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Nationwide View of Essential Soil Erosion Control Measures - - - - - - - *B. P. Fleming*

Responsibility of Engineers in Agricultural Reorganization - - - - - - - - *W. R. Woolrich*

Ferrous Metals as Used in Agricultural Machinery - - - - - - - - - - *H. Bornstein*

Looking Ahead to Better Houses on American Farmsteads - - - - - - - - - - *Wallace Ashby*

Development of the Porous Hose Method of Irrigation - - - - - - - - - - *O. E. Robey*

Analysis of the Farm Implement Type of Spoked Wheels - - - - - - - *O. B. Zimmerman*

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CONTENTS

A NATIONWIDE VIEW OF ESSENTIAL SOIL EROSION CONTROL MEASURES 267
By B. P. Fleming

RESPONSIBILITIES OF AGRICULTURAL ENGINEERS IN AGRICULTURAL REORGANIZATION 273
By W. R. Woolrich

FERROUS METALS: THEIR TREATMENTS AND PROPERTIES FOR AGRICULTURAL MACHINERY 276
By H. Bornstein

LOOKING AHEAD TO BETTER FARMHOUSES 280
By Wallace Ashby

THE DEVELOPMENT OF THE POROUS HOSE METHOD OF IRRIGATION IN MICHIGAN 282
By O. E. Robey

SANITATION IN RELATION TO THE PRODUCTION OF FARM COMMODITIES 284

ATHLETE, SOLDIER, SCIENTIST, ENGINEER 286

A TECHNICAL ANALYSIS OF THE AGRICULTURAL IMPLEMENT TYPE OF SPOKED WHEELS 287
By Oliver B. Zimmerman

AGRICULTURAL ENGINEERING DIGEST 302

EDITORIALS 304

NEWS 305

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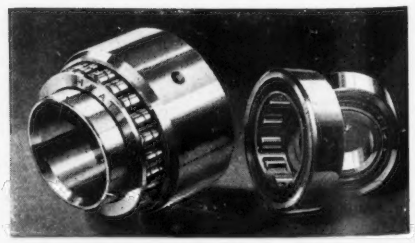


HYATT

ROLLER BEARINGS

PRODUCT OF GENERAL MOTORS

A Nationwide View of Essential Soil Erosion Control Measures[1]

By B. P. Fleming[2]

IF EVER a realistic portrayal of the life and times of the first 140 years of this nation is written, the story undoubtedly will revolve around a principal theme, the thirst of our citizenry for land, always more land. The original thirteen states were not what might properly be termed crowded with population, but no sooner was the war of the revolution fought and ended and the domestic difficulties inherent in the formation of a stable government successfully overcome, than the yearnings of the adventurous spirits of the time for new and better lands resulted in a westward wave of emigration which never stopped until it met the western ocean.

We who had no part in the reconstruction period following the Civil War, know nothing of the pioneering spirit of those days which opened up the prairie states and the mountainous west to settlement, but those of us who are middle-aged can remember something of the stirring days which preceded and followed the opening of Indian Territory and resulted in the great state of Oklahoma of today. This was merely an illuminating episode in our time of the great drama occupying the first century of our existence as a nation, the central theme of which always was the urgent quest for land, cheap land, virgin land, but always land over in the next county or state or across the river or beyond the distant mountains.

Many of the seekers of land found it in regions where all the cards were stacked against them. Yet no matter how unpromising the surroundings or how slim the chances of making a living seem to be, there, in the most out of the way parts of this country, you will find even now the ubiquitous home seeker, his pathetic wife and maybe a few children struggling somehow to make a living out of the soil.

This urge ever to seek a foothold on the soil of God's footstool is something inherent in our make-up, a welling-up, if you please, of primitive instincts and habits that are among the most deep-seated of our emotions. Land, then, is our inherent need; it is the backbone of our national economy. And yet with all this passion for land, this consuming desire which has opened America from the Ohio to the Pacific in three generations, we apparently have done little with our land but exploit, uncover, dig into, scratch, and abuse it, until today we suddenly waken with horror to a realization that the "land of our fathers", this beautiful, never-failing source of wealth and contentment, is rapidly becoming a thing which "the fathers" scarcely could recognize. The valleys and plains, the mountains and the hills are in the same geographical location, but in many cases surface changes due to soil wastage and erosion have been so extensive as almost to change the face of nature. The old homestead is in the same location as described in the deed, but it is not the same land that was offered as security for the mortgage. Grandfather set his plow deep into a fertile humus or top soil. His grandson cultivates with difficulty a barren subsoil.

From the time of the settlements at Jamestown, with few interruptions down to the present, we can trace in this country an unremitting exploitation of the soil. When first broken up and cultivated, it yielded plentifully. As time went on and generation after generation of farmers (or rather let us call them cultivators and planters) continued to stir up the surface soil, it was noted that the crops kept getting ever more sparse and thin. Then came the urge to move on to newer virgin lands. "The old lands are worn out; let us sell them, for anything they will bring, load the family and the furniture into the wagon, tie the chicken coop on behind, and strike out for the land flowing with milk and honey behind the mountains." Thus the Plains States came into being; thus Oregon was settled; thus the frontier was pushed ever westward. Now there is no longer a frontier. Out in the vast stretches of remaining public domain is no unexplored territory. The present generation will never exercise its homestead right as so generally did its fathers and grandfathers, for there is no suitable land left on which to file a homestead. True a man can go out on some vast mesa, some blistering desert, and file his homestead if he is the type of fellow who knows no better

[1]Paper presented before the Land Reclamation Division at the 28th annual meeting of the American Society of Agricultural Engineers, at Detroit, Michigan, June 18-20, 1934.

[2]Regional director, Soil Erosion Service, U. S. Department of Interior.

(LEFT) TRACTOR AND TERRACER AT WORK ON THE TALLAPOOSA COUNTY (ALABAMA) TERRACING PROJECT. (RIGHT) TRACTOR AND DISKS DOUBLE CUTTING AN AUSTRIAN PEA COVER CROP IN THE SAME COUNTY. THE COVER CROP IS PART OF THE COUNTY'S SOIL EROSION CONTROL PROGRAM

than to spend his time in such a futility. The days of free land, of virgin land, are now but a memory.

As we ride through parts of the South, we are impressed by the vast stretches of apparently vacant and idle land, but I am told that a reconnaissance across the state of Georgia some time ago revealed the surprising fact that forested areas, supposed to be virgin soil, revealed the evidences of cultivation possibly 100 years ago and were the site of farms so long abandoned that the oldest inhabitants had no recollection of them. There are a few places, even in the great prairie states, where the prairie soil is undisturbed. Certainly there is no denying that in the arid west few if any areas now remain which are suitable for irrigation which were not developed, exploited, and perhaps abandoned even before the beginning of the present era. Consequently when some opponent of the "New Deal" rises to criticize the land conservation and land use program of the present administration on the grounds that we have more land now than we can use, he perhaps is unaware that although we may be unable to use properly that which we have, yet it will not pay us to abuse and waste it, for in the continental United States, exclusive of Alaska, there is now little or none to replace that which we spoil. It also is well to remember that we have learned there are few lands which have become infertile merely by continuous cropping, unless it be on some of the few very flat sandy areas of our country. Lands have become sterile, not so much by loss of plant food, as they have by continued loss of top soil by excessive soil washing.

The Policy of the Soil Erosion Service Is to Conserve Soil Resources

In the great fabric of activities new and old which now characterize the federal government in its efforts to restore some measure of prosperity to a stricken nation, it is sometimes difficult to discern a pattern. The threads often seem confused and tangled. In nothing is this more pronounced than in what seems to be a contradiction between the general policies of the Department of Agriculture and those of the Department of the Interior, as evidenced by the activities of the Soil Erosion Service. The former is endeavoring to reduce the amount of land in cultivation, in order that we may not produce unmanageable surpluses. The latter is apparently trying to help the farmer save land which may be used for the growing of crops that produce the surplus. "Why not," say the critics, "let Nature take its course. If lands become ruined and therefore no longer productive, by so much will it be the easier to control surplus production." So easy (if cold-blooded) a policy might be a proper one for this nation to adopt, if we had no regard or thought for generations yet unborn, and if there were an inexhaustible supply of new and virgin lands upon which these future generations might settle. In the face of the fact that most of the lands it is possible to farm in America have either a present or a past tenant, and as earlier pointed out, there is no longer a frontier across which there is a wealth of new lands, it seems only a common sense view of things to assume that it might be well to pay some attention to the preservation of what we have. That in brief is exactly the policy of the Soil Erosion Service.

It seeks to introduce no improved cultural methods which will increase national production. It seeks not to reclaim or to put into production lands that are now unproductive; rather it encourages the taking out of production of lands which experience teaches never were suitable for cropping purposes. Its whole program revolves around the one thought of soil saving. It says to the farmer, "We fear your present practices are wasting your top soil. We fear you soon will find you will have nothing but subsoil to cultivate. Let us reason together and see if, by some change in your cultural methods, we can not preserve this farm for your children. Also let us see if there are not lands you are now trying to farm which are too steep or too worn to be farmed profitably and which should be in woodlands or pasture."

The Soil Erosion Service goes out west and it notes the melancholy results of drouth and overgrazing on the great public ranges. It is alarmed by the increasing violence of floods from denuded watersheds. It advocates as a policy the public regulation of grazing and such artificial means of impeding run-off and trapping silt as will encourage revegetation of the ranges and prevent the ultimate submergence under silt and debris of the civilization in the irrigated river valleys.

Millions of Acres of Land Becoming Worthless Due to Soil Erosion

In brief then, the policy of the Soil Erosion Service is soil conservation. Certainly no more apt or timely program could be proposed at a time when, under the stimulus of a national calamity, we have paused for self-examination to see where as a nation, immersed for so long in money-grabbing and the greedy pursuit of easy profits, we have been ruthlessly wasting our natural resources and creating possibly intolerable conditions and impossible problems for our children. A nation whose soil resources are wasted and washed away by erosion through careless and improvident methods of cultivation, cropping, or grazing can have no happy future regardless of the wealth in its mines, its quarries, and its forests, or those fundamental resources in the intelligence and genius of its people.

The inventory which the present federal administration has been taking of our national business, reveals the disconcerting fact that on the debit side of the ledger is 35,000,000 acres of land formerly cultivated, but now almost worthless by reason of soil erosion. Ten times that area is still under cultivation, but of that nearly one-third has lost its valuable surface soil by gullying and sheet erosion. Potentially, therefore, an area equal to one-half of the cultivated area of the United States is ruined or soon will be for cropping purposes. Moreover, it is estimated that the remaining area of good soil is being reduced at the rate of 100,000 acres a year by soil erosion. In a country which has no longer any reserves of virgin soil to which future generations can turn, the condition as described above seems a most serious one. Our traditional answer to any warning of soil wastage has been, heretofore, "Oh! we have plenty of land; why worry?" With our reserves of land used up it is time to worry. The present crisis in overproduction or of underconsumption, however you wish to view it, will pass. Consumption again will overtake production. Nature will reassert itself. Children will continue to be born and population probably will continue to increase. The time inevitably will come when all available land will be needed for feeding and clothing our population, or at least all land that offers the cultivator a reasonable opportunity to win a respectable living from his efforts. Collectively much could be produced on our large extent of erosion-impoverished land, but the producer is necessarily a submarginal farmer on submarginal soil (subsoil rather).

Fortunately the federal administration has decided to do something more than worry about the problem. It has decided for the first time in our history to intervene, and if possible arrest the tragedy of exploitation of our soil. The intervention, however, is to be a friendly one. Demonstration, cooperation, encouragement toward self-help and

(LEFT) AN EXAMPLE OF GULLY EROSION WORKING BACK INTO THE AREAS OF A FARM IN THE SOUTH, ABANDONED BECAUSE OF EROSION. (RIGHT) THIS VIEW SHOWS A ONCE PROSPEROUS FARM IN THE SOUTH WHICH HAS LOST MUCH VALUABLE SURFACE SOIL BY SHEET EROSION

direct aid, where circumstances warrant it, all are a part of the nationwide program now rapidly taking form.

Specifically, the program so far has involved the creation of twenty-four projects in that many states, these projects in the humid sections involving the complete watershed of some stream on which erosion conditions are typical and for the most part severe. In the arid west a different situation is encountered, and the program is accordingly modified as will be referred to later.

On each project is a regional director selected for his ability as an executive and for his knowledge of local conditions and skill at improvising remedies to meet them. Under him is a staff comprising one or more agricultural engineers, soil experts, agronomists, silviculturists, and contact men or extension agents.

The program is a simple one, consisting essentially in an effort to enlist the farmers of the locality in a system of improved cultural methods designed to reduce soil wastage. The change must, however, come about entirely through cooperation. No coercion, naturally, can be employed; the individual must be shown that it is entirely to his interest to adopt new methods before his cooperation can be secured. With those who express a willingness to cooperate, the federal government enters into a contract. The government agrees to lay out the farmer's fields in terraces, contour furrows, or other ways to arrest soil washing; it agrees to furnish him with seeds or cuttings of plants useful in preventing further erosion of gullies, and in some cases it provides the heavy or special equipment necessary to the building of terraces, or it agrees to contribute a nominal sum toward their construction. It agrees also to protect the cooperator's land from the drainage of other lands above it. The government does not agree to build terrace outlets, stop gully erosion, or take care of the general problem of flood control to prevent erosion. Much of this work, however, has been done by the CCC workers in camps located on the watersheds. The farmer, for his part, agrees to cooperate by following instructions in the redesign of fields; he agrees to contribute man and horse labor and any suitable materials his lands may provide for stopping gully erosion. In many cases the farmer is induced permanently to take out of cultivation lands which are too steep or too badly eroded ever to be farmed with profit. In such cases the Soil Erosion Service cooperates with the farmer in deciding upon such tracts, in the relocation of fences to isolate them, and in adapting them to other uses such as pasturage or woodlots. Much land too steep to farm will be returned to the forests which once covered it, and the Service cooperates by securing proper trees to grow upon such areas.

A long-range policy, on which the Service hopes some time to realize results, is in line with the general policies of the Department of Agriculture, in that, on general areas now badly eroded, too steep for cultivation, embracing thousands of acres perhaps or a whole watershed, farming in the ordinary sense would be discontinued, and the lands would be devoted to the growing of forests by some plan essentially similar to that followed in parts of Europe. Thus in a measure a new form of rural activity would be initiated, sponsored and supported perhaps by the state, or perhaps by the county or the nearest municipality. In time such areas would become revenue-producing, whereas, under the present system of farming, they are merely a trap to lure some poor tenant farmer or owner into the spending of time and labor in the attempt to grow crops which the denuded character of the soil foredooms to failure, no matter whether the price of farm products be up or down.

Although not specifically enlisted in the carrying forward of the government's program of retirement of submarginal land, the Soil Erosion Service, on its various projects, is acquiring very pertinent information as to soil characteristics and slopes which determine the susceptibility of such lands to future erosion, information which has an important bearing upon the government's purchase of marginal or submarginal lands that should be retired from cultivation before erosion starts or before it becomes so extensive as to be a menace to property values below it. The Soil Erosion Service believes there are lands which never should be farmed, because they cannot be other than a disappointment to the farmer. Its knowledge of these conditions and circumstances should be of assistance to those who are directing the land use policies of the federal administration.

The cooperation so far secured from the farmers on its various project areas has been most encouraging largely for the reason that the program is a practical one. Terracing is not offered in every case as the general panacea, neither is contour furrowing, nor strip cropping, nor rotation. The greatest care is being exercised in making recommendations. The soils are studied, the slopes measured, and the surface drainage investigated before a farm plan is proposed. An attempt is being made to attack the problem from the standpoint of a well-coordinated program, including cropping measures, forestry measures, engineering measures. Special care is being exercised in investigating the adaptability to new environments of certain plants which in their original habitats have proven of value in stopping surface erosion

and gully washing. Thus lespedeza in some places has proven an ideal soil catcher in strip cropping, while it and wild honeysuckle, Bermuda grass, sweet clover, black locust, Kudzu vine, and a great many other plants have proven useful in some localities in consolidating the soil and preventing the spread of gullies or in stabilizing them. In other places such plants might prove a pest and the greatest care must be exercised in introducing them where they have not previously grown. As a consequence, experimental nurseries are being established on certain of the projects where under rigid control various species of soil-saving plants can be tried before they are introduced generally. The search for suitable plants of this character is being extended over the world generally, and it is not unlikely that some exotic plant eventually may be found which with a dense root development and a prostrate habit of growth may prove ideal for protecting the slopes of washes, terrace outlets, ditch banks and other places exposed to the tearing action of water.

In the last analysis we, who represent the engineering profession, must realize and confess that the ultimate and widespread solution of the soil erosion problem cannot depend wholly upon engineering measures, but rather upon Nature's own processes of healing through revegetation. Engineering measures are merely palliatives. If we except the dams built by beavers, Nature did not provide check dams under primitive conditions to prevent erosion and gullying. The natural growths of vegetation took care of and prevented soil washing. It was only when man began ripping up material sod with his plows, cutting down the forests and uprooting the stumps and destroying with fire what vegetation he failed to kill with tools, and in other ways destroying Nature's delicate balance, that soil began to be washed in quantities into the streams and to be moved by the winds, and we began to have an erosion problem.

The Soil Erosion Menace Has Existed in This Country a Long Time

We have, as a matter of fact, had this soil erosion menace as a natural problem for many long years. A few experienced observers knew what was going on and by word and pen told us where we were heading. The hideous gullies opening up here and there through cultivated areas, the premature filling with silt of reservoirs for power and water supply, the choking of culverts and bridge openings, the disappearance of fish in the streams we once knew, all were evidences of a condition of which we were too dense to realize the cause. We blamed these abhorrent things that were happening to the countryside on Nature. We were too blind to realize that man and his stupidities were to blame. We may have cause to be thankful that our eyes have been opened. The publicity being given to the problem by the Soil Erosion Service will of itself be of untold benefit to this country, and the demonstrational areas located in the various states will serve to focus the attention of the farming population upon symptoms and remedies in a way that cannot help but be useful in saving American soils for the succeeding generations of American farmers.

In the arid West the erosion problem is somewhat different from what it is in the humid states. In a humid region vegetation is generally dense enough so that only long-continued and widespread attempts by man to subdue the earth by cultivation result eventually in damage by accelerated erosion. In a good pastoral country in such regions, it is not likely that grazing ever could be so far overdone except in drouth periods, as to result in serious injury by gullying and surface soil loss. On the other hand, in the arid West quite the contrary is true, although the rainfall may be so scanty as to lead to the question how

FILLING THE STORAGE RESERVOIR WITH SILT IS NO LESS SERIOUS IN THE EAST THAN IT IS IN THE WESTERN UNITED STATES. THIS PICTURE SHOWS A RESERVOIR IN SOUTH CAROLINA PRACTICALLY FILLED WITH SILT AND ITS STORAGE CAPACITY ALMOST ENTIRELY GONE

there could possibly be damage by running water. The answer is that vegetation is scanty at best, and the rains which do fall are likely to be concentrated in a few showers of great intensity. If then the protective cover of vegetation is removed from the areas on which such showers do fall, the resultant soil washing and gullying is apt to be quite as severe as in a country with greater rainfall. Wind also is quite as destructive a soil remover as is water in certain parts of the country. Immense damage has been done in grazing countries by homesteaders' ill-considered efforts to plow up the prairies. Spring winds strip the naked surface of its top soil and pile it in dunes against the nearest windbreak. Soil erosion by winds and waters in the arid West has been accelerated and expedited by the public lands policy of our government.

There seems to have been a passion on the part of the lawmakers of this nation in the half dozen decades following the war between the states to rid the nation of its area of public lands. By the Homestead Act with its various amendments, the Desert Land Act, and other acts calculated to promote settlement by homeseekers, vast areas passed into private ownership, although not always with profit to the owner. Then by grants to railroads, other great areas passed out from the control of the government and largely into the hands of private interests. Other blocks were ceded to the states and these have been sold or leased in large part to private interests. Finally, there entered into the sovereignty of the United States, along with the areas acquired from Mexico by treaty and purchase, the great tracts known as the Spanish Land Grants.

As a result, today we find in the West sections in which public domain, patented lands, railroad lands, state lands, and perhaps a land grant are grouped together. Over such an area no effective control of grazing is possible, unless by strong arm methods some individual has acquired a dominance. Generally, however, the present ranges have become badly overstocked, under the peace and quiet which has succeeded the swashbuckling era of a generation ago, when cattle and sheep wars occupied the news now dominated by the Dillinger type of gang. On the unfenced and accessible public domain, there has been intense competition for whatever grass there might be. As a result, particularly in years of drouth, the grasses and herbaceous vegetation have largely disappeared. Following a heavy summer rain, water flowing over the surface in sheets carries with it

surface soil, seeds, and whatever humus there may be. This water concentrates in the nearest water course and soon we have one of those most interesting as well as terrifying spectacles, an arroyo in flood. Such a stream may have a vertical wave front six feet or more in height, surmounted with foam and debris. It sweeps down the bed of the arroyo at a velocity of 10 to 15 feet per second. An automobile caught in the bed of an arroyo by such a flood is rolled over and over down the stream and may later be found partially buried beneath sand gravel. Boulders weighing tons are rolled along the bed of the stream and one of the characteristic sounds of an arroyo in flood is the rattle and boom of boulders clashing against each other as they are rolled about by the force of the current.

After a heavy and prolonged shower, one lasting say an hour, and with a precipitation between one and two inches of rainfall, every little depression has its miniature arroyo busily engaged, not only in conveying surface soil, but in eroding what it can from its own channel. A thousand such miniature arroyos combine to form the big one, which may be so silt laden that its specific gravity may be increased enough to account for its ability to transport boulders that velocity alone cannot explain. Such a stream accumulates great quantities of additional material by bank cutting, particularly where (as is often the case) the banks are of alluvial formation. All this material is swept onward with the rush of waters toward the main river channel. If any farm lands in the river valley intervene they are covered with debris dropped by the flood as its velocity is diminished. A few such successive arroyo floods over irrigated lands raises them above the level at which they can be reached by gravity irrigation and they return to the desert. Quantities of water-borne detritus eventually reaching the river may be deposited in its bed or the delta at the mouth of the arroyo may force the river to change its channel.

Rising river bed from arroyo debris is a characteristic of all torrential rivers of the Southwest. If reservoirs are built across them for irrigation, their capacity for storing water is depleted rapidly, so rapidly that it is doubtful if the people really can afford to pay for public improvements so ephemeral in character.

This brief and very inadequate picture of erosion in our arid regions indicates that a corrective program there can have no resemblance to one in the humid regions. On the Navajo Indian Reservation in Arizona and New Mexico, it is true that a demonstrational program is being devised. This is for the reason that it is readily apparent the Navajo Indians have been improvident in the way they have stocked the reservation with sheep and goats, resulting in denudation of vegetation and consequent accelerated erosion which is rapidly making the range conditions infinitely worse and eventually, if not corrected, will irrevocably ruin a great portion of the reservation, leaving the Indians to starve. Since the reservation is the Indian's country, it has been judged proper and worth while to attempt to show him how he can arrest the continued rapid erosion of the lands of his reservation, and possibly avert the serious consequences which must follow a few more years of abuse of tribal lands. In addition to demonstrating to the Indian the measures which he himself can use to bring back the vegetation and prevent the washes from digging great trenches into the heart of his grass lands, it is true that the government will undertake certain major construction and revegetation programs, necessitated by the advanced state of destruction in which parts of the reservation are now found.

THIS ARROYO IN AN ALLUVIAL VALLEY, ONCE HEAVILY CRUSTED, IN ARIZONA, IS WORKING HEADWARD AT THE RATE OF ONE-FOURTH MILE A YEAR

But however much it may do for the Indians who always have been the wards of the nation, what can the federal government do to improve conditions which through accelerated erosion are already acute on the vast areas of public domain? It is of no use to put on a demonstration of corrective measures over a watershed of 100,000 acres, as one does in Illinois, for example, for on the watershed of a destructive arroyo tributary of the Rio Grande, let us say, no one lives; it is all public land and there is no hope of either public or private agencies being encouraged to carry on the work elsewhere, no matter how convincingly effective the demonstration may have been. Certainly neither public nor private agencies in the western states have the means (even if they had the inclination) to carry on so extensive a program as the stabilization of the watershed of any one of our principal western rivers would prove to be.

Soil Erosion Control and Revegetation Needed in the Southwest

The Gila River above the Coolidge Dam in southeastern Arizona and western New Mexico is a stream which, including its tributaries, is misbehaving badly, threatening to fill Coolidge reservoir with silt at a comparatively early date, and both the main stream and its tributaries are actively eroding and cutting and carrying away the alluvial valleys they formed in past ages. Eight and a half million acres are involved in this portion of the watershed, and over $5,000,000 is estimated as necessary to make a start toward so stabilizing the watershed of this river as will in some degree correct the serious conditions now prevailing. For such rivers, when the watershed is largely public domain, one of the first essentials is to bring about control of grazing, so that Nature may have a chance to start corrective measures through the process of revegetation. The federal government, after having brought about control of grazing, might then very properly undertake to do what seems humanly possible to do, by check dams, silt barriers, revetments, detention reservoirs, and other suitable works to assist Nature in bringing about a restabilization of the watershed. Fortunately this is all work of a character which would give a maximum of employment to idle hands. Check dams are one form of engineering work where you need no machinery, the most extreme mechanical aid being possibly a stone boat dragged by a horse and used for gathering big rock from the countryside.

So far the federal government has engaged in no extensive work of this character, but in the opinion of the author it is an extremely serious mistake for the government to approve the plans and appropriate money for the construction of great dams on silt laden streams, until at the same time it is ready to embark on a plan for stabilization of the watershed above the dam in the interests of control of erosion and of silt. Certainly, I for one am positive in my

belief that our grandchildren, contemplating the mud-filled flats which perhaps fifty years from now will take the place of the present lakes back of our principal storage dams, will regard the mighty dams we have erected across several of our silt-bearing streams as nothing more than everlasting monuments to the stupidity of the age in which we live.

Engineering phases of the erosion and silt control program must of necessity be much concerned with problems of flood control when these are reduced to their lowest terms. The soil erosion engineer is concerned with the rills and rivulets where erosion starts. He realizes that if he can bring them under control it will greatly simplify and possibly eliminate entirely the silt problem and the flood problem on the main stream and its major tributaries. Here again we have illustrated the old story of the bundle of twigs which could be broken twig by twig, but resisted rupture as a whole. Our chief difficulty is to find engineers who have the genius and the patience to deal with small things. Our engineers have been trained to think in terms of big figures, great masses, immense floods. To get down to the ground and deal with the minor structures, the small but complicated problems having to do with the design and construction of small check dams, terrace outlets, and similar little structures seems almost unworthy of their attention, and were engineers not now the victims of the worst and longest period of unemployment the profession has ever experienced, we might have difficulty in staffing our projects. The engineering is not highly theoretical. It calls largely for the exercise of judgment and common sense. Much of it is rough and ready adaptation of local materials to the solution of local construction problems. These engineers must be fertile in expedients, highly inventive, and with nimble minds that will be quick to reject preconceived ideas in favor of some plan or expedient that will more readily fit the conditions.

One problem that bothers those working in this service, as it has doubtless any who have had to face and solve flood control problems, is that of run-off and the intensity of storms. For what degree of safety shall structures be designed? Shall we who are dealing with soil erosion problems attempt to design structures which will safely pass floods of the character of those which occurred at Montrose, California, the last of the year 1933? Fortunately such storms are not general over a watershed, and even more fortunately the flood crests from individual tributaries do not always reach the main stream at such times as contribute to its principal flood crest. It might as well be admitted frankly by the engineering profession that even though money were no object, it would be an impossibility to design and build flood control structures capable of giving 100 per cent protection to life and property. Always at some time that extraordinary storm will occur which beats all records for length and intensity. It is likely to occur at any time, and, when it does, the most substantial structures man can devise are apt to fail. We, therefore who have to do with soil erosion and silt control should build as substantially as possible but should never give the general public the impression that what we build is proof against all floods. Moreover, we are not building major flood control works. Primarily our problem is to arrest soil washing and for the most part our works should be described as silt barriers.

Again we are under the necessity of working within limited budgets and of covering vast expanses of territory. Economy of money not only is a factor, but various other factors are involved, such as necessity of using local materials so far as possible, eliminating long material hauls, and the like. All of these factors have led and will be an increasing stimulus to the evolution of novel, untried, and more or less experimental types of structure. Conventional structures designed along conservative lines in concrete, masonry, or steel, may possibly be employed at strategic points, or points where failure of structures not so well designed or built would involve great loss to life or property. Thus the Los Angeles flood commission is justified in employing the most modern methods of design and the safest and most substantial methods of construction for flood control dams in San Gabriel Canyon or Sierra Madre Canyon, where a failure would cause enormous property damage and loss of life in the numerous and thickly settled communities of Los Angeles County. On the other hand, a soil-saving dam on some tributary of Big Elm Creek, which if it failed merely would flood some small farming area in the lowland, might be a structure built for economy rather than extreme safety, and in its construction conventional ideas of construction might be replaced by others which gave promise of saving in time and expense.

In this paper I have attempted to give you a glimpse of the program and a hint as to the problems of the Soil Erosion Service. It is a new bureau of the U. S. Department of the Interior. It has been organized and at work less than eight months, yet in that time it has spread its activities into half the states of the Nation and is actively at work spreading the gospel of soil conservation. Primarily it is a vast program of education based upon demonstration and self-help. If it only partially succeeds in its purposes and objectives, it will have performed a service for America that will be functioning long after the present national emergency is but an unhappy memory.

Terracing for America's Idle Farmlands

THE SOIL is America's one permanent asset. It may be kept permanently productive, or by erosion be permanently lost. Appalling as soil loss may be under normal cropping, it is likely to be far worse under what could correctly be called a fallow condition. If we are to have a planned national economy, and reduction of tilled acreage is to be part of it, any subsidy on idle land should surely be conditioned on the permanent protection of that land—or other land on the same farm—from eternal destruction by erosion.

Cover crops have their helpful place, of course, but they are merely mitigants of the moment. If the American people are to invest millions or billions in the relief of agriculture, they should demand in return a guarantee of ample and reasonably cheap food for the generations to come. The only basic thing in that is physical preservation of the soil from washing to the sea.

Agricultural engineers know both the gravity of the problem and the methods of its solution, and they urge combining erosion control with any national plan for acreage reduction. They have pointed out that crop vacancy gives chance to get onto the land; that idle acres imply spare man-power and availability of farm machinery which may be put to terracing.

Most agricultural engineers are experts by virtue of training at public expense; some of them are in public employ. In simple fairness they should use that trained judgment by urging far-sighted measures for the welfare of all America. Erosion control is such a measure.

Responsibility of Agricultural Engineers in Agricultural Reorganization[1]

By W. R. Woolrich[2]

INDUSTRIALLY and agriculturally America has experienced two levels of progressive advancement, and is now emerging into that third and highest zone of human achievement.

The first level was that of daring romance, during which period prevailed that adventurous urge to search the frontiers, to uncover the storehouses of hidden wealth, and to battle man, beast, and nature in the name of patriotic and he-man endeavor.

The second stage carried her into a prolonged period of materialistic rugged individualism. So long as this individualism had some unselfish vision there was social and economic justification. But under the economic pressure of competition and manipulated price levels, high ideals gave way to the fight for existence. The result was a general exploitation of lands, of forests, of rivers, of minerals, and of human life itself.

The great jar of 1929 suddenly brought the nation to its senses. The magnitude of that rupture indicated that it was one of those evolutionary thumps that existing competitive life on Mother Earth has experienced at intervals of every three or four centuries.

Fortunately, and some of us think providentially, the national presidential mantle fell on the shoulders of a man who recognized the significance of this pronounced disturbance, and who proceeded to lead his countrymen onto that higher or spiritual level that inspires "old men to dream dreams and young men to see visions" of their responsibility to their fellow men, to their community, and to their national government.

During this early history of our nation, patterns have been changing rapidly in industry, in agriculture, in education, and in governmental methods. Few give thought to the fact that in the last eighty years more changes have taken place in industrial and commercial methods than had occurred in the entire eight thousand years of known history prior to 1850. In other words, in one per cent of world economic history over 50 per cent of industrial changes have occurred. A modern year evolves more changes than the average one hundred years developed prior to the later half of the 19th century.

Our early pattern of industry was to confine it to large industrial centers. The workers were corralled in mill villages where they would be readily available when the whistle blew. Our slow methods of travel made this pattern desirable. Not only was it convenient to have the employes near the factory, but the plants themselves found it convenient to be in concentrated areas. The effect of such a development is revealed today in the presence of nearly seven-eighths of our American industries in one-tenth of the counties of the nation.

The change in this pattern was ushered in by the development of cheap automobiles and good roads. Prior to 1900 the world had not witnessed the production of one thousand automotive road vehicles in all history. By 1903 America was ready for mass production in cheap motor cars, and by 1928 we had one car for every four people within our national boundaries.

The result on industry has been its diffusion into agricultural areas. This is especially marked in the Tennessee Valley where the invasion of industrial plants occurred largely after 1900, and to an area whose climate would permit highway travel virtually 100 per cent of the working days of any year.

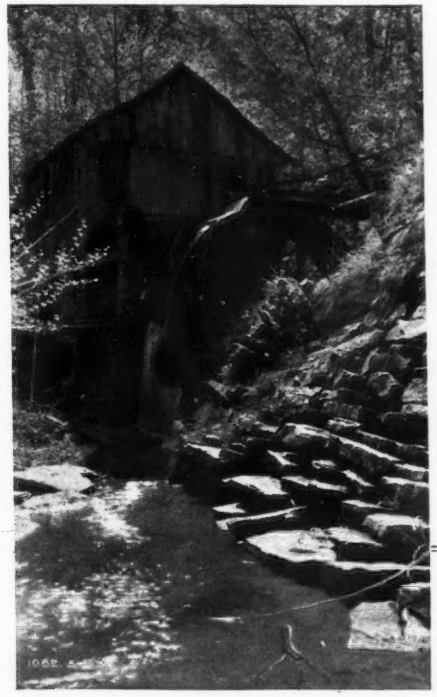
In agriculture, likewise, our patterns are rapidly changing. In the years past a successful farmer was one who could buy a farm at one price, live on it for twenty years, and sell it at a price that represented enough increase in his dollars to permit him to retire to the rural city.

Proprietorship in land in the United States gave the owner autocratic rights in its use. That these autocratic prerogatives were exercised is evidenced by the recent announcement that over eighteen million acres of the nation's more fertile lands have been sacrificed forever by the past generations. The recent legislation of several of our states indicates a new interpretation of land rights.

With the rising increment of land values removed as a semblance of livelihood security in our national picture, part-time employment in industry appears to be the greatest aid to the tiller of the land.

Another great change that is anticipated in the American agricultural pattern is the elimination of tenancy. Many of America's keenest brains are facing this curse of American home life with a determination to strike hard at its root structure.

If we turn now to our changing patterns in education, we find a



THIS OLD MILL AND WHEEL, LOCATED IN THE TERRITORY OF THE TVA PROJECT, WERE BUILT IN 1885 AND THE MILL, WITH ITS ROCK BURRS, IS STILL IN ACTIVE SERVICE. IT WILL, HOWEVER, BE SUBMERGED BY THE NORRIS DAM

[1]An address before the 18th annual meeting of the American Society of Agricultural Engineers, at Detroit, Michigan, June 18-20, 1934.

[2]Chief, general industry and mechanical research division, Tennessee Valley Authority.

development equally as challenging. Only one hundred years ago, three out of every four boys and girls were farm trained. The goal of most of these farm lads and lassies was that of owning a farm and to "be on their own."

By 1934 less than one out of every three boys and girls in the United States were farm trained, and the nation suffers from a great army of city-trained position seekers. They must fit into the great mosaic of industry and trade with but little guidance of compass or prophet to live a life of ever-changing outlook and possibility.

How shall that young man or young woman proceed?

Too often they are told to specialize. Specialize in what? In what trade or profession could one have attempted to specialize in 1900 that would equip him for today's work? The specialized man is a desirable asset to the employer when that employer needs such specialized training. But the day the job specification changes, his limited training places the employe at a disadvantage and too often he is thrown on the human scrap heap. Certain major choices might be made early in life, as between law, engineering, home economics, literature, medicine, etc. But future differentiation can well be delayed to later life.

Finally, the fourth-mentioned change, that of the science of government, deserves thoughtful consideration. With all shades and degrees of governmental philosophy being practiced in the social and industrial rehabilitation in Europe, some of these demonstrations being so iconoclastic as to overthrow all of the old and recognize only the new order in these foreign nations, there is necessarily a question of great insecurity in the home life of the individual. He knows not what hour the whole procedure of governmental activity might change and repeat another eruption confiscatory to property, to home, and to life itself.

While these millions of humanity of the several foreign nations are shuffled from one philosophy of life to another at the will of some dictatorship, America, a nation that has gone on by election with practical demonstration of communism, of socialism, of democracy, and, during war periods, with rigid autocracy, plans and directs a national laboratory of some two million people in the Tennessee Valley, who themselves, with federal guidance, will seek out a better order of regional planning that might be used by the nation.

The Readjustment of Agriculture in Companionship with Industry

Any permanent recovery program must necessarily be based on a readjusted agriculture in companionship with industry. Such a readjustment of agriculture will include such basic problems as:

1 Its diffusion with industry
2 The control of soil erosion
3 The promotion of investigation, research, and industry in relation to land use and conservation
4 The restoration and maintenance of plant food
5 The exploration of the economic and social objectives of rural life.

The diffusion of industry will be accompanied by a greater absorption of the rural population in industry with the elimination of the need of so-called "company houses." In the rural counties of the Tennessee Valley the surplus population not now needed for either industry or agriculture varies from five hundred to three thousand workers.

A survey in some of these purely rural counties indicates that often the people left at home in the counties are only the children and the older people. The birth rate in these counties is much above the United States average. At the ages of twenty-one to forty-five, the census reports show these people have left the county at such a rate that the total number of people at this age of life is considerably below the United States average. At fifty to fifty-one years, we find that many of these same people return to their rural county after they have been thrown on the scrap heap from some industrial center where they have spent the major portion of their useful life.

A better diffusion of industry with agriculture will help materially in correcting this maladjustment. The incoming of industry will also justify more farm electrification by bringing more cash money to support the electrification project, and incidentally the industry can also carry part of the rural electrification line construction costs.

Our experience has proven that the coming of an industry into the rural area can help much in reducing the tax burden so long as the areas themselves adopt a code of fair competition and refrain from offering incoming new industries a bonus of free taxes for a term of years. Any freedom from taxes offered to the industries is manifestly unfair to the farm property holders, who are not granted any such consideration, but whose burden is increased by the extra public expenditures occasioned by the coming of the industrial enterprise.

The Control of Soil Erosion in the Readjustments of Agriculture

Much might be said about the control of soil erosion by or for this readjusted program. Some of the methods of attack in the southern areas must be:

1 A reduction of cultivated crops, such as corn and cotton, to produce legumes and several cover crops of equal value.

2 The development of a livestock production program that will encourage more pastures on the steep slopes.

3 The encouragement of a greater diversity of marketable products by closer association with industry, thus distributing the labor of farm operation more in uniformity throughout the year and stimulating closer attention to the improvement of lands through an active crop and livestock development.

The promotion of investigation, research, and industry in relation to land use involves:

1 A study of small farm agriculture, with new demands for implements and equipment.

2 The development of new types of machinery for weed elimination and for seed improvement.

3 The adaption of simplified electrical appliances peculiar to rural needs.

4 The development of facilities to adjust seasonal production so that communities will not have to sell on low and congested markets and buy back the same produce at greatly advanced prices.

5 The development of new industry based entirely upon new uses of standard and introduced agricultural crops in the reorganized type of agriculture.

To effect the restoration and maintenance of plant food in our agricultural areas will involve:

1 A better utilization of soil researches of state and federal governments to rehabilitate land by more liberal use of fertilizer.

2 Continued experiments to discover new processes of manufacturing and producing the fertilizer needed.

3 The development of new methods of distribution of fertilizers.

4 The making possible of greater facilities for more generous use of lime and phosphate on legume and grass lands to meet nitrogen needs and to accelerate soil erosion control.

AN AIRPLANE VIEW OF THE NORRIS DAM CONSTRUCTION IN THE TENNESSEE VALLEY, SHOWING QUARRIES, COFFER-DAMS, AND CONSTRUCTION EQUIPMENT FOR THE PROJECT

The exploration of the economics and social objectives of rural life offers a challenge to the engineer that he too often tries to evade. If engineers are to take their active place in readjustment programs, they must give more thought and attention to economic and social objectives of rural life.

Problems that might present themselves immediately are:

1 The study and demonstration of the possible effects of companionship of self-containment and mass production.

2 A study and demonstration of community effort upon the success of individuals.

3 A study of the influence of rural electrification and the development of recreational areas in the stabilization of farm communities.

Basically, America is struggling (1) under an unplanned distribution of industry, (2) under a false philosophy of the economy of plant size, and (3) under a mistaken idea that concentration of people within a corporate zone brings prosperity to the city which has coaxed others to join the number of city dwellers.

The failure of America to evenly intersperse her industry and agriculture brings a distribution surcharge that for many of our basic products adds several times more to the cost than the labor and material value of the product. It was one of the principal contributing factors that presented the paradox of starvation with plenty in our American commonwealths.

Turning to plant size, the very nature of overgrown institutions precludes their ready adaptability and their response to the new order of industrial change. Visualize, if you will, a nation entering a period of accelerated changes in plant products, plant methods and commercial practices, and at the very hour when it needs great mobility of readjustment in her industries, there develops designs of dinosaur proportions. At this time we have a number of large American industries with new products in their palm, but by virtue of their size dare not hazard a change.

Now if we consider this third factor under which America struggles, that of making big cities bigger, we are forced to injure our own civic pride. Haven't chambers of commerce, local newspapers, and many civic clubs cast their vote for such "megaopolis" developments?

It would be an interesting story, however, for some enterprising investigator to study and reveal how many cities of over fifty thousand population, who secured new industries to come within their corporate limits between 1924 and 1929, have found it necessary to carry a large proportion of these same workers who were coaxed into that city from the rural areas on the municipal relief rolls of their adopted home.

This entire mosaic of factors that must be readjusted, if the people of the United States are to maintain their supremacy as a free nation with individual opportunity for all, presents a great challenge to every agricultural engineer within our borders. Here is a national problem dependent in its solution on a better adjustment between industry and agriculture. What national organization is closer in its relationship to both major enterprises than an engineering group thoroughly grounded in agricultural technic?

In its activities in which this organization has been actively engaged, it will require increased emphasis in:

1 Improving the mechanization of the farm home to remove drudgery in the heavier and the more tedious activities.

2 Developing wider uses for electricity so that the farm home is more attractive than the city dwelling.

3 Extending the programs of land reclamation by new and improved devices and measures.

4 Designing farm structures that will utilize the available materials with due attention to artistic sense and to economic adaptation.

The Place of the Agricultural Engineers in the Readjustment of Agriculture

But as we strive to attain this higher plane of readjusted agriculture, we must look to this organization to assume additional responsibilities. Some phases that will permit greatly increased activity are:

1 The standardizing function of machines adapted to farm life so that the consumers whom you serve will have some better measuring stick of the goods they purchase.

2 The development of new machines that will fit into the interspersed agriculture and industry movement.

3 The insistent simplification of home equipment now purchased under city codes that will adapt itself to the great mass of farm users without undue burden of initial investment.

4 A program of definite procedure in training rural youth in carpentering, masonry, house wiring, and plumbing to restore more of self-sufficiency to farm life practice.

Considering these separately and in order given, the standardizing of farm machines and equipment will first be discussed.

The American Society of Mechanical Engineers has successfully functioned as the standardizing agency of a wide range of developments. Likewise, the American Society of Civil Engineeers and the American Institute of Electrical Engineers have actively participated in the standardizing function. But in rural equipment little has been accomplished, yet the rural consumer in much less able to employ competent advisors than those in other types of enterprise. The American Society of Agricultural Engineers could well take her position as the standardizing authority for farm equipment before this function has been too widely distributed to numerous other agencies of more commercial intent.

The development of new machines that will adapt themselves to the limited size of farm is very urgent. It is no recommendation to American engineering that one state is finding it more economical to employ steers as plow animals on small tracts of twenty acres and less. Our farm machine business, built on the basis of the mass production methods of the midwest. must be reorganized to fit the increasing number of small-acreage farms of the land.

Should the farm machine business take refuge under higher prices to meet the declin- *(Continued on page 279)*

Ferrous Metals: Their Treatments and Properties for Agricultural Machinery[1]

By H. Bornstein[2]

I HAVE BEEN connected with the metallurgical side of agricultural machinery manufacturing for the past fourteen years. Looking back, I can see considerable improvement in the ferrous materials used in the production of agricultural equipment. Under the term "ferrous materials" I am including steel (forged, rolled, pressed, or cast), gray iron and white iron castings, and malleable castings.

Steel. When I first entered the farm implement manufacturing business, the specifications for raw materials in respect to steel were very broad. For example, most of the steel which we purchased would come under the following headings: soft Bessemer steel, hard Bessemer steel, soft open-hearth steel, hard open-hearth steel, and old-rail steel.

This type of specification of course gave the supplier of the steel considerable leeway, but it did not give the implement manufacturer a uniform product. These loose specifications have been replaced with specifications which are considerably more definite in respect to composition, physical properties, etc.

A few years ago Bessemer steel was quite a large factor in the farm implement industry, but today it is used to only a very small extent, and it is rapidly passing out of the picture, except for screw stock.

The range of composition used in the agricultural implement industry is a very wide one. For rolled steel products, the carbon content ranges from less than 0.10 to over 1.0 per cent. In the higher carbon contents a good deal of the material is subjected to heat-treatment. The amount of alloy steels used in the implement industry has been relatively small. It is only in the automotive end of the industry,—in the manufacture of tractors,—that a considerable quantity of alloy steel is used.

The question is frequently asked, "Why use alloy steels?" In the first place, alloy steels are usually better made and more carefully made than carbon steels, and consequently they are more uniform and better in respect to physical properties. Furthermore, the use of the alloys usually means an increase in strength for the amount of ductility or increased ductility for the same amount of strength. Also, alloys are used for specific purposes such as improvement in wear resistance, machineability, etc.

The use of alloys is also valuable in the heat-treatment of steels. On heavy sections we obtain a considerably better hardness penetration with an alloy steel than with a straight carbon steel. Also, in certain cases alloy steels can be oil-quenched with a minimum of distortion, while the carbon steels would have to be water-quenched to secure the same range of physical properties.

There has been a large increase in heat-treatments over the past few years. A good many parts are now being heat-treated which were formerly not heat-treated. To a considerable extent this is due to increased stresses resulting from using mechanical power in farming. The heat-treatment results in an improvement of physical properties. No definite rule can be laid down for the heat-treatment of various parts; it will depend upon the material used, the design of the part, and the physical properties required. In some parts it is satisfactory to confine the heat-treatment to a quench, while in other cases a tempering treatment is required after the quench.

The quality of heat-treatment has improved considerably with the development of heat-treatment equipment. Continuous furnaces, where the heating cycle is mechanically controlled, and automatic temperature control have done much to eliminate variations due to the personal equation and limitations of equipment.

In a paper of this length, it is not possible to give detailed compositions and treatments covering the important implement parts. However, I will cite two examples.

Since the introduction of tractors, plow beams have been heat-treated. Following is the composition, treatment, and properties of a typical plow beam:

Carbon	0.680 per cent
Manganese	0.620
Sulphur	0.032
Phosphorus	0.028

TENSILE PROPERTIES AND HARDNESS

	As received	Quenched from 1600 deg F	Drawn at 1000 deg F
Elastic limit, lb per sq in	48,200	99,500	93,500
Ultimate strength, lb per sq in	98,600	152,600	139,500
Elongation in 2 in, per cent	15.0	14.0	15.5
Reduction of area, per cent	30.9	30.9	37.3
Brinell hardness	192	302	275

It will be noted that the heat-treatment has resulted in an increase in ultimate strength of approximately 50 per cent, but the elastic limit has increased about 100 per cent.

Harrow and plow disks are made from high-carbon, open-hearth steel and are now being heat-treated. A typical analysis would be carbon 0.90 per cent and manganese 0.85 per cent. The disks before heat-treatment would have a Brinell hardness of about 228. After an oil quench and draw, the Brinell is increased to about 387.

For the plow beams, the heat-treatment was used to

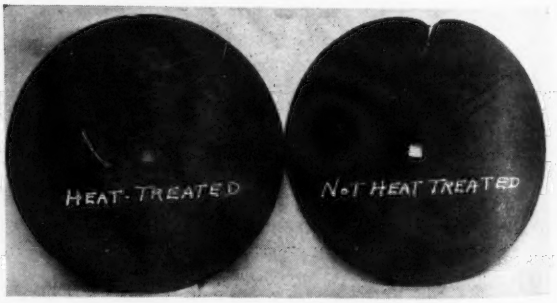


FIG. 1 SHOWING RESULTS OF DROP TESTS ON IMPLEMENT DISKS. HEAT-TREATED DISK AT LEFT SUFFERED PRACTICALLY NO DAMAGE, BUT THE NON-HEAT-TREATED DISK AT RIGHT WAS BENT AND TORN

[1]Paper presented before the Power and Machinery Division during the 28th annual meeting of the American Society of Agricultural Engineers, at Detroit, Michigan, June 18-20, 1934.

[2]Director, testing and research laboratories, Deere and Company, Moline, Illinois.

increase strength, while for the disks, the heat-treatment was used to increase wear resistance and strength.

In the testing of disks, a drop test was developed to indicate the shock strength. In Fig. 1 is shown a heat-treated and a non-heat-treated disk which have been subjected to this test. The heat-treated disk has suffered practically no damage, while the non-heat-treated disk was bent and torn.

For many years soft-center steel has been used for hard plow shares. This is a three-ply steel, the outer layers being high carbon steel (about 1.00 per cent carbon) and the center layer being soft steel (about 0.1 per cent carbon). After heat-treatment the outer layers are file hard, while the center is soft and gives toughness to the product. Fig. 2a shows the structure of the hard layer and Fig. 2b shows the structure of the soft center.

Malleable Cast Iron. The advancement in malleable cast iron over the last 14 years has resulted in an increase in both tensile strength and ductility. Going back to 1921 we find American Society for Testing Materials standard specifications for malleable castings calling for a tensile strength of 45,000 lb per sq in and an elongation of 7.5 per cent. The current specifications of the ASTM call for two grades of malleable castings, the lower grade having a tensile strength of 50,000 lb per sq in, a yield point of 32,500 lb per sq in and an elongation of 10 per cent. The higher grade calls for a tensile strength of 53,000 lb per sq in, a yield point of 35,000 lb per sq in and an elongation of 18 per cent. It is obvious that there must have been quite an improvement in physical properties of malleable iron castings in the last few years to justify such a change in the specifications for the product.

In making malleable cast iron, a white cast iron of suitable composition is first produced. The structure of this material is shown in Fig. 3a. The carbon is all chemically combined as iron carbide. The metal is then put through an annealing treatment in order to change the carbon from the combined to the free form. Fig. 3b shows such a product. The black spots are free carbon or "temper carbon." Where the annealing treatment has not been carried out properly, an intermediate product may result, such as shown in Fig. 3c. This material is brittle, due to presence of iron carbide.

Special types of modified malleable castings have been developed in the past few years where the tensile strength has been increased to a figure of about 75,000 lb per sq in with an elongation of 10 per cent or more, together with considerably greater hardness. The hardness of the ordinary malleable casting is in the neighborhood of 135 Brinell. For certain purposes this does not give good enough wear-resisting properties. The modified product has a Brinell hardness range in the neighborhood of 175 which means increased wear resistance.

Besides this type of product, there is what I would term a "semi-malleable" type of casting. A white cast iron is used and a very rapid heat-treatment follows which results in a product having a high tensile strength with a fairly low ductility. It is a product which is intermediate between gray cast iron and malleable cast iron. It is possible that this type of product will have a wide application for agricultural implement parts.

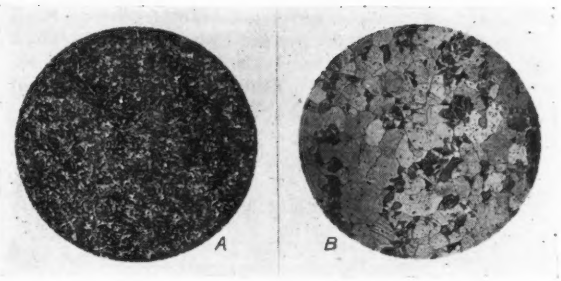


FIG. 2 MICROGRAPH OF SOFT-CENTER STEEL HEAT-TREATED — A, OUTSIDE LAYER; B, CENTER LAYER

In discussing malleable castings, I wish to point out that it is our experience that castings fail because of (1) unsoundness in the casting and (2) incomplete annealing rather than because of low physical properties. Our present specifications call for 50,000 lb tensile and 10 per cent elongation. We do not have failures because the tensile strength has dropped to 45,000 and elongation down to 7 per cent. We do have failures, however, when the casting is unsound, or where the annealing treatment or composition has been such so that the structure is an incompletely annealed one, resulting in a brittle material.

Gray Iron Castings. The improvement in gray iron castings has been quite marked in the past few years. Only a dozen years ago, in the implement foundries, steel was used to a very limited extent in the cupola charge. I recall one of our foundries which was using 6 per cent of steel in the mix and referring to the product as "semi-steel." Most of our foundries at that time were using no steel in the mix. The gray iron castings of that period were soft and low in strength. There has been an improvement in melting conditions in the foundry as well as in the mechanical end of the foundry. The metal is turned out under metallurgical supervision, and the strength has been considerably improved.

The highest tensile strength provided for in the ASTM specifications in use in 1921 was 24,000 lb per sq in minimum. This was for heavy castings. On light castings, a minimum tensile strength of 18,000 lb per sq in was specified. In the current specifications of the ASTM we provide various ranges of tensile strengths up to a minimum of 60,000 lb per sq in. This is an indication of the improvement in gray iron castings during this period.

A few years ago the use of alloys in cast iron was practically unknown. Today a considerable quantity of gray iron castings are alloy cast iron. Nickel, chromium, molyb-

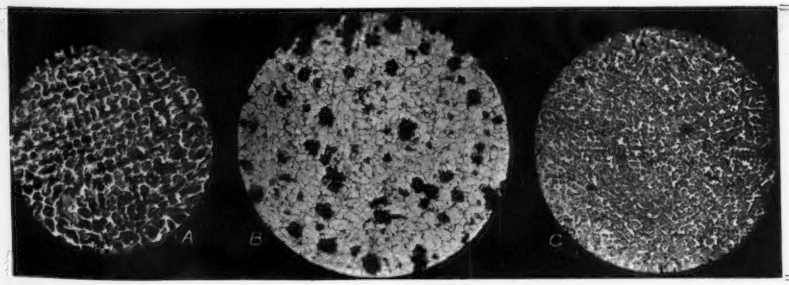


FIG. 3 MICROGRAPHS SHOWING STAGES OF PRODUCING MALLEABLE CAST IRON—A, WHITE CAST IRON USED FOR MAKING MALLEABLE; B, THE METAL AFTER THE ANNEALING TREATMENT; C, RESULT WHEN METAL IS INCOMPLETELY ANNEALED

denum, and other alloys are widely used in producing better gray iron castings. In some cases the addition of these alloys is for strength, in other cases for wear, and in still other cases for improvement in machineability. However, it should be borne in mind that the large bulk of gray iron castings are non-alloy castings.

There is considerable difference in structure between the soft weak cast irons and the high-strength cast iron. These are illustrated in Figs. 4a and 4b. Please note the larger graphite particles in the soft iron. Also the soft iron has considerable ferrite or iron free from carbon, while in the stronger metal the iron is practically all in the combined form.

Heat Treatments. A few years ago the heat-treatment of cast iron was in its infancy. There was some work done on the annealing of cast iron for machineability and for the removal of strains. Today, gray cast iron is being quenched and drawn in order to obtain castings which are considerably harder, somewhat stronger, and more resistant to wear. This is a field which will probably be considerably developed in the next few years.

One of the tractor manufacturers is using a heat-treated alloy iron cylinder liner and the minimum Brinell hardness is specified at 450.

Significance of Tests. Hardness tests are very much in use because they are non-destructive tests and are easily made. The more popular hardness tests are Brinell, Rockwell, and Sclerescope. The Brinell hardness test is perhaps the most popular of all, and other hardness tests are frequently translated into Brinell hardness numbers. Conversion tables are available for this purpose.

In the case of steel parts, the Brinell hardness is a good index of the tensile strength of the material. It does not, however, give us an indication of the other tensile properties, such as elastic limit, per cent elongation, and per cent reduction of area. In cast iron and in malleable iron the Brinell test is of very little value in respect to indicating strengths, except in specific cases.

The Brinell Hardness Test Used to Indicate Strength of Castings

In comparing strengths of castings, where the foundry practice and the composition have been pretty well established, the Brinell test may be used as a good indication of strength. We had a gray iron casting used for structural purposes, where the strength was an important factor. We were abie to tie in the Brinell hardness on this particular casting with the transverse strength and with the tensile strength of the material. In this case, therefore, we were able to use the Brinell test as a good indication of the strength, and a minimum Brinell hardness was specified for this casting. However, our Brinell specification would probably have to be revised if the castings were made in another foundry, where there would be a difference in the metal used and the foundry practice.

The hardness test is very frequently used in checking up on heat-treated parts. A certain heat-treatment is specified for a definite composition of steel (or other material) and the heat-treated part is then checked up by a hardness test. If the hardness range is satisfactory, it is a good indication that the proper materials and treatments were used.

Attempts have been made from time to time to correlate hardness and wear resistance. For similar materials and treatments it is possible to establish a correlation in specific instances. However, it is not possible to choose two different parts at random and attempt to correlate their wear resisting properties on the basis of hardness tests. We have found the composition of the material to play an important part in wear resistance. Of course, the structure of the material, as examined under the microscope, is quite important, and this in turn depends upon composition and treatment.

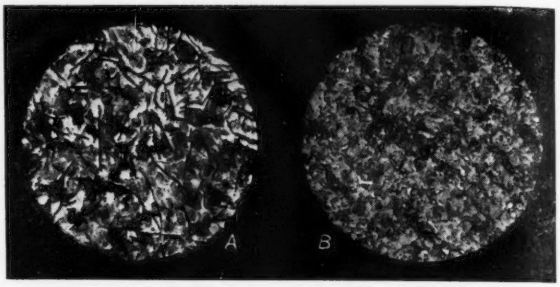


FIG. 4 MICROGRAPHS SHOWING STRUCTURE OF CAST IRON: A, SOFT CAST IRON; B, HIGH-STRENGTH CAST IRON

In the case of steels, we have frequently found a lower Brinell hardness material to give us better wear resistance than a higher Brinell hardness material. However, in this case there was a considerable difference in the composition of the material. For the same material, we have usually found the higher Brinell hardness to give the better wear resistance.

In the case of cast iron, we have found the structure to be very important, and the hardness is only one factor pointing towards the wear resistance of the material. In the case of white cast iron, we have found the higher hardness to be desirable in resisting wear.

Attempts have also been made to correlate hardness and machineability. This is practically impossible on dissimilar materials, but on similar materials the hardness acts as a guide towards indicating the machineability. For certain parts, it has been found advisable to set upper limits for hardness in order to come within practical range of machineability.

Strength. Strength tests are usually made on test bars which are taken from the piece in question or are separately cast. Wherever possible, it is desirable to make a strength test on the entire piece and then establish a correlation between such a test and a test on a test bar. The tests on the entire piece should be similar to the loading in service. Too many tests are made on bars which give results which are not at all indicative of the results to be obtained in service.

The tensile test is the best known of all physical tests. It is the test which the designers best understand. However, it is very difficult to translate tensile strength, elastic limit, elongation, and reduction of area into field performance. Sometime we need an increase in stiffness rather than an increase in strength, and additional expense is incurred for higher priced materials and treatments which are of no value in this case. All that is required in such a case is an increase in the size of the part in order to obtain greater rigidity.

In this connection, I want to cite one example in our own experience. At one time we ran experiments with various alloy steels for use in plow beams. These beams had sufficient tensile strength, but they failed in service because of lack of rigidity. A slight increase in the section size gave us the desired results, and it was possible to go back to an ordinary carbon steel for this part.

In gray iron castings, the loading is frequently a transverse loading or a compression loading. Cast iron members are not frequently used in pure tension. While the tensile strength of gray iron castings has been materially improved in the past few years, it should be pointed out that the

transverse strength, as expressed by the modulus of rupture, is greater than the tensile strength. Where a casting is going to be used under transverse loading, it is well for the designer to utilize the transverse strength of the cast iron and obtain more economical results. The compressive strength of cast iron is several times the tensile strength, ranging from three to five times the tensile strength, the smaller ratio applying to the stronger irons and the higher ratio to the weaker irons.

Design and Materials

It is desirable that the design of an implement should be such that lower cost materails can be used. Frequently high-cost materials and expensive treatments must be used to make up for deficiencies in design. Good design should permit of a sufficient factor of safety with the use of materials which will give an optimum overall cost. Too frequently the design is on the ragged edge, so that it is necessary to be overly fussy in the specifications for materials and treatments. This means a burden for the supplier of the material and an added expense for the manufacturer of the implement.

An implement is composed of many parts. The manufacturer does not sell the individual parts but the machine as a whole; and the functioning of the entire machine is important rather than the material or treatment used in each individual part. One manufacturer may use an expensive alloy steel heat-treated for a certain part of an implement, while another manufacturer may use ordinary cast iron for the corresponding part of a similar implement. However, the design may have been such that the cast iron part will function satisfactorily and the machine as a whole is satisfactory. On the other hand, where the heat-treated alloy steel part was used, the design may have been deficient and the extra material and heat-treatment was required. It would therefore not be at all correct to say that the use of the alloy steel part was more desirable.

It appears to me that there is a danger in attempting to standardize materials and treatments for various parts of farm implements. In certain cases, such standardization may be desirable, but it might become distinctly harmful if carried too far.

Responsibilities of Agricultural Engineers in Agricultural Reorganization

(Continued from page 275)

ing demand, they might repeat the unfortunate experiment of those railroads who tried to cover their losses by increased rates only to find the substitute carriers taking the major portion of the remaining business even from the railroad's best friends.

Recently I observed one extensive area that was harvesting its 1934 wheat crop with cradle scythes. The scythe had so completely solved the high-priced equipment problem in that region that in a distance of twenty miles over sixty cradle scythes were counted in the fields as compared with five grain binders.

Simplification of farm equipment is closely related to any program of increased self-containment. This simplified equipment development, coupled with an extensive program of adult training in the mentioned trades, will restore much of the hope and inspiration in the American home owner. The advertised philosophy that one's time is worth too much to him to attempt such projects is usually very faulty. Your time and my time is not worth one cent more than you and I can realize on it at the period you and I have available for such enterprises. A high-priced consulting engineer might well afford to work for himself at a net saving of twenty cents per hour, if he has no other place to use his energies more profitably at the time the twenty-cent opportunity presents itself. Incidentally, as a spare time enterprise, he might acquire some valuable impressions that would make him much more sympathetic with workmen who are normally employed for the twenty-cent type of job.

Finally, we might carry this simplified development to our farm home construction. A survey of those homes that were successfully meeting their mortgage requirements revealed that the average American farm home could not support a cash expenditure much beyond 15 per cent of the fair land value of the farm. Thus, on this basis, a $6000 farm is limited to about a $900 cash outlay if the mortgage is to be lifted in a reasonable period of time. Prices "primped up" for city folks by elaborate building code requirements have no place in a readjusted agricultural program. The cream of American rural homes has been taken care of in our various home improvement campaigns, but the great mass of small homes, if they are to become a part of the national improvement program, must be reached by more simple and lower-priced equipment.

Engineer Charts Frequency and Intensity of Heavy Rains

TO SUCCESSFULLY design a municipal storm sewer system large enough to take care of the storm water safely and within the appropriations available, engineers must know how much rain is ever likely to fall in 5 min, in 15 min, and in an hour or more. They also need to know how often these sudden downpours are likely to occur. Engineers planning terracing systems on farmlands, farm drainage systems for surface water, and culvert waterway openings for small watersheds must also have this information for best results.

Recently D. L. Yarnell (Mem. A.S.A.E.), agricultural engineer, U.S.D.A. Bureau of Agricultural Engineering, finished charting rates of precipitations and their frequencies for the 206 federal weather bureau stations which have automatic rain gages. The data cover periods of from 10 years up to 30 years or more.

Certain localities have been interested in records of the intensity and frequency of short heavy rains in their own vicinities, but this is the first attempt on the part of any individual or agency to coordinate this information for the entire country.

Because a storm of great intensity usually extends over only a small area, Yarnell believes that this study is sufficiently comprehensive for a reasonably accurate estimate as to how often a rain of a given intensity is likely to occur in any region of the United States. He cites the Baltimore, Md., station. From its records, it is possible to tell how many heavy rainstorms of short duration are likely to occur in any month of the year for that city and vicinity. Once in about five years, for a 5-min period, the citizens of Baltimore and vicinity can expect a rainfall at the rate of 6.2 in an hour, or 0.51 in in 5 min; once in 10 years a rain at the rate of 6.82 in an hour, or 1.14 in in 10 min. Based on the 0.51 in in 5 min on a city lot 50-by-100 ft, 212 cu ft, or 1,588 gal of water would fall. In building a house, this quantity must be drained from the lot if the cellar is to remain dry.

For a period of 38 years, 1896-1933, the maximum amount of rain that ever fell at Baltimore in a 5-min period was 0.70 in, and for a 15-min period 2.08 in. Yarnell's charts show the maximum amounts for periods of 5 min up to 400 min.

What has been charted for Baltimore, has also been charted for each of the other 205 weather bureau stations in the United States that have automatic rain gages.

Looking Ahead to Better Farmhouses[1]

By Wallace Ashby[2]

THE RURAL housing survey, which formed a part of CWA program, had two objects. One was to provide productive work for unemployed people in rural areas, especially women, as part of the huge civil works program which provided employment for four million persons. The other object was to measure the needs and problems involved in rehabilitating the farm homes of the nation. These problems are important because they are closely related to the general economic situation. Money spent for farm home improvements will contribute toward national recovery by direct employment of labor as well as through indirect employment resulting from the use of materials.

The short-time objective of immediate relief through employment on the housing survey was accomplished satisfactorily through the cooperation of the state colleges and the agricultural extension service. Nearly 5,000 people were put to work within a month from the time the project was begun. Work in some states started within a week. Workers were paid for their services at an average of about $180 each. For the most part, they worked faithfully and energetically to gather the information that was wanted, and their reports form the best picture that has ever been presented to show the rural housing situation in this country. The money paid out was a godsend to many of the workers—the first some had earned in more than two years. It was badly needed for rent, clothing, grocery bills, doctor bills, and other necessary purposes.

I think most of you are familiar with the general outline of the survey project. It covered 352 counties in 46 states. Complete general schedules were obtained for approximately 630,000 farmhouses, and estimates of the costs of improvements needed were obtained for about 25,000. The survey was directed by Dr. Louise Stanley, chief of the U.S.D.A. Bureau of Home Economics, who is greatly interested in rural housing and also has the advantage of being in close touch with the county home demonstration organization. The Bureau of Agricultural Engineering, the Agricultural Extension Service, and the Office of the Secretary of Agriculture, cooperated in the direction of the survey, the Bureau of Agricultural Engineering being responsible for the schedules and tabulation of the engineering data.

The Survey Provided Information on Repairs and Equipment Needs

In most of the surveyed counties all the farmhouses were visited by women enumerators who obtained very complete schedules regarding the condition of the houses, housing needs, expenditures for repairs and improvements during the past three years, and the anticipated expenditures for repairs and new buildings. Information was also obtained on the relative importance of various types of repairs, equipment needs, and the like, and the willingness of the householder to borrow in case money were available for long-time loans at low interest rates. An engineer in each county obtained for a smaller number of houses much more detailed information about the cost of needed repairs, new buildings, and installations of equipment needed, and also secured a limited amount of information about the expenditures for buildings other than the dwellings during the past three years and the proposed expenditure for 1934.

A survey of rural electrification was made in typical counties of twenty-five states to learn the extent of present distribution of electricity to homes and the possibility of extending distribution lines to farms not now served. This survey also included details of existing line extension policies, location and adequacy of power sources, and other pertinent information. Supplementary studies of hospital and public library facilities were also made in many areas. Thus the survey has provided much of the information needed as a basis for a broad program of rural rehabilitation.

Organizing and Carrying on of the Survey Proved to be an Involved Problem

Many difficulties arose in organizing and carrying on the work. At the time the survey was begun the Government Printing Office was filled with rush orders for the AAA and the NRA in addition to the regular work. This caused unavoidable delay in sending out printed schedules and tabulation sheets to state and county workers and made it necessary to mimeograph large quantities of forms that might well have been printed. This no doubt caused much inconvenience. There were many misunderstandings about appointments and methods of procedure which were unavoidable in a hastily created organization of such size, and there must have been many discouragements on account of delays in payment of wages and expense accounts. Other difficulties were encountered in the way of floods in the Northwest and bad roads in many places. Many of the workers traveled on foot or on horseback because bad roads prevented using automobiles. In spite of these difficulties, the field work was carried on and finished in a very creditable manner. Reports from field workers indicate that the farm people they visited received them well in almost all cases and furnished the desired information freely. One enumerator reported, "I found people most ready to answer questions," and another, "At only one place have people refused to give me information." These comments were typical of letters received from the survey workers. Probably this receptive attitude on the part of farmers was due, in part, to local news articles and radio addresses about the survey, as well as to the selection of good survey workers and the real interest which farm people have in their homes.

The data of the survey are comparable to those taken by the federal census, and while a large part of the work of tabulating was done in the states, it has been necessary to do much additional work in Washington in checking the tabulations and compiling summaries. This will require considerable more time for completion.

Probably each of you is more familiar than I am with the results from your own state, but I have a brief summary of results for the country as a whole which may be of interest. This is based on incomplete information and probably the figures will be somewhat altered when the tabulations are finally checked.

As you know, there are in the United States about 6¼ million farmhouses. The survey indicates that probably

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[1]A report presented to the Structures Division of the 28th annual meeting of the American Society of Agricultural Engineers, at Detroit, Mich., June 18-20, 1934.

[2]Chief, division of structures, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Mem. A.S.A.E.

50 per cent of them are in fairly good structural condition. Many are poorly arranged and lack modern conveniences, but at least the houses are reasonably sound. This speaks well both for the men who built them and for the owners who have taken care of them during the past lean years. On the other hand, about 15 per cent of the houses need complete replacement of foundations; between 15 and 20 per cent need replacement of roofs; 10 to 15 per cent need floors replaced; and about 10 per cent need extensive repairs or replacement of exterior walls. Between these extremes of houses in good condition and those needing complete replacement of parts or of the entire house, are a large group needing extensive repairs of some kind, including much interior refinishing.

The survey engineers reported the estimated cost of repair and other work needed in their counties to put the farmhouses in good livable condition. Based on preliminary tabulations of these reports, the cost of needed repair work if paid for on a cash basis at rates prevailing in the spring of 1934 would amount to the immense sum of perhaps three and one-half billion dollars. This is an average of about $575 per house and on this basis does not seem unreasonable. There is a great difference, however, between the amount needed to put farmhouses in good livable condition and the amount that farmers feel able to spend. They spent for repairs and upkeep during the past three years an average of about $75 per house. They contemplate spending during 1934 about $25 per house, or about 4 per cent of the estimated amount needed. Even allowing for inaccuracies of estimate, this can only mean that a large amount of needed work will be put off for the present and that the average house will continue to deteriorate. A similar situation exists with regard to modernizing of present houses and the construction of new homes. Here, too, the needs run greatly in excess of actual intentions of farmers to build. For example, estimates indicate that about one million new houses costing an average of about $2500 apiece are needed, but only about one-fourth million farmers actually contemplate building within the next three years. The average size of the intended houses is only 4.6 rooms and the expected cost is about $1060 per house, not including the owner's work. Evidently the total new construction for the three years will also be far below the total need. This discrepancy between what is needed to provide adequate housing and what the farmers feel able to do under present circumstances, presents a tremendous problem.

The Demand for Farmhouse Plans Is Heavier Than Usual

While the present outlook for better rural housing is rather discouraging, there are many indications that the situation is going to improve. Statistics show that the national farm income is steadily increasing, and this should enable many farmers to make improvements later on which they cannot afford at present. Even now, though the percentage of farmers who are planning immediate improvements is small, the total number is large. The Bureau of Agricultural Engineering is receiving heavier demand than usual for farmhouse plans, as well as for all kinds of information on remodeling, and many letters say that work is to be started at once.

A factor which may have great influence on future developments is the administration's housing program. The Housing Bill just passed will provide easier financing for both farmers and townspeople who wish to make home improvements. As I understand it, one purpose of this program is, as the President has said, "the ultimate objective of making it possible for American families to live as Americans should." Another object is to develop a volume of work which will absorb the idle labor in the building and material-manufacturing industries and thus help to break the economic deadlock that has held us since 1929.

I believe that the members of this Society can take a part in such a program which will be helpful to all concerned. Our functions, as I see them, are to develop and make available the technical information needed for building better farmhouses, and improving those already built; and, secondly, if a program of rehabilitation is undertaken, to assist in carrying it on in an organized way. The local contacts of state people should be most valuable in this connection, for much of the success of any organization depends on knowing the people who can and will do what needs to be done.

There is an increasing demand on the Bureau of Agricultural Engineering for instructions on all sorts of repair and remodeling work, and probably you are receiving similar requests. Fortunately there are a number of helpful publications, but little information, except trade literature, is available on several kinds of work such as foundation, roof, and wall repairs. State or federal bulletins on such subjects are needed.

Plans for Low and Moderate-Cost Houses in Preparation

For several months the Bureau of Agricultural Engineering has been receiving many requests for plans for new houses. A good deal of progress has been made in this direction since the rural housing project was begun. A small fund for preparation of plans for low and moderate-cost homes was made available to the Bureaus of Home Economics and Agricultural Engineering. We shared this with eighteen state colleges in order to obtain plans which would be representative of all sections. The cooperating states were Alabama, Arkansas, California, Georgia, Kansas, Indiana (Purdue), Illinois, Iowa, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, Ohio, Texas, Virginia, Washington, and Wisconsin. More than 100 preliminary plans were prepared and forty of these have been put in fine shape. These were worked out to meet farm needs and the requirements of good design through the joint efforts of agricultural engineers, home economists, and architects. Arrangements are being made for publication in bulletin form and also for distribution of the working drawings to farmers through the regular plan-exchange channels.

Plans for remodeling also were prepared by some of the state workers. We are putting these plans and material from the survey in shape for publication. The Bureau of Home Economics is working on a bulletin on kitchens.

The department of agricultural engineering at the University of Wisconsin and the Bureau of Agricultural Engineering are cooperating in making a moving picture of a very interesting remodeling job. I think that with this combination of state and federal efforts, the subjects of plans for new houses and for remodeling are being fairly well taken care of.

There are two technical phases of the housing problem which I think are not receiving sufficient attention. The first of these is farmstead arrangement. The building and relocation of improved roads, the breaking up or consolidation of land holdings, the use of the automobile and motor truck, and other factors are causing relocation of many farmsteads. I believe that proper location and arrangement of the farmstead deserves more study, and I would like to suggest it as a subject of research.

The other technical problem concerns farmhouse construction. The typical farmhouse of today certainly leaves much to be desired in the way of both comfort and safety, and is not especially economical. I am sure that better and cheaper construction is possible, though I do not know just how it ought to be done. These are problems on which we all ought to be working, for the cost of present construction is one of the things that is holding farmers back.

Finally, there is an immense need for farm home improvements and other developments, such as rural electrification, which will promote better living conditions for farm families. The problem is engaging the attention of leading men and women, and well-directed efforts are being made to find ways of improving conditions. The members of this group of the Society are in a position to be of great help, but to keep our place in the farm housing field, we will have to devote our best energies to it and keep fully in touch with and cooperate in the activities of other groups.

Development of the Porous Hose Method of Irrigation in Michigan[1]

By O. E. Robey[2]

THE DEVELOPMENT of irrigation in Michigan has depended entirely upon the construction of individually owned installations. There has been no attempt to build large irrigation projects such as are found in some other states. There are a number of reasons for this. The contour of our soil is such that large type irrigation projects are not practical. Our rolling land and variable soil make every field a special problem.

In this state we do not have a general shortage of rainfall. Our average for the whole state is 32 in a year, and when properly distributed is adequate for ordinary crop growth. There has been no necessity for building dams and reservoirs to impound water for irrigation purposes. Our state, besides being nearly surrounded by some of the largest lakes in the world, is dotted over with 5,000 small lakes and interlaced with 2,000 streams which make water readily available to a large proportion of our farms. Underground water supplies are easily tapped. While in some cases it is necessary to put down wells from 200 to 400 ft deep in order to secure water for irrigation purposes, in a large proportion of the state water is available at a depth of from 10 to 100 ft.

For a number of years there have been a few large and many small overhead irrigation systems working in this state on crops of sufficient money value to warrant the investment. There also have been a few installations where irrigation by flooding or by the trench method has been practiced, but this method has not become generally popular because of some of the natural difficulties previously mentioned.

The spread of irrigation in Michigan has received considerable impetus through the use of porous hose. This method of irrigation has overcome a great many of the natural difficulties which we have had to encounter in this state. It has made it possible to use irrigation on land that is slightly rolling without expensive leveling of the fields. It has also offered a solution to individual irrigation problems, which in many cases were of an emergency nature and required a comparatively low investment. By means of porous hose the irrigation of field crops has been made economically possible.

It is not my purpose in this paper to go into any details regarding the first two methods of irrigation, namely, the overhead and the trench system, because we have not made any contribution in either methods or results which would be worth considering at this time.

In the development of the porous hose method of irrigation, we do not claim originality. Many others, no doubt, tried this scheme years ago and for some reason or other abandoned it. The history of all discoveries has been more or less the same. Selden and others conceived the idea of horseless wagons years before Olds, Ford, Chrysler, and others began building a practical automobile. If any credit is due us, it is because we have been able to adapt this method to meet our peculiar irrigation requirements.

Interest in irrigation in this state began to develop in 1929-30 when there was an appreciable deficiency in rainfall. Instead of our usual 32 in of rain, we had only 18.5 in in 1930, and instead of our usual summer rainfall of 10 to 12 in we had only about 5 in in 1929 and 1930.

It was through the insistent demand by farmers of the state during these two years for some sort of a solution of the irrigation problem that we hit upon the porous hose idea. While experimenting with heavy canvas hose as a means of conveying water for flooding, we conceived the idea of tying a knot in the end of the line of hose and using it as a means of distribution.

We tried out this method of distribution in 1931 on a few experimental plots of potatoes of about ½ acre each in various parts of the state. The simplicity of the method and the results obtained seemed to appeal to both the farmer and the general public. The description of this method of irrigation got into the newspapers, and people from this state and surrounding states and even from foreign countries came to see the water applied on some of our plots.

The next year a few farmers around the state had enough faith in the method to try it out on areas of two or three acres. The areas irrigated and the number of farmers using it have gradually increased until we have entirely lost track of the number using this method of irrigation in the state. I might say that 10,000 copies of the bulletin which I prepared on the porous hose method of irrigation to help some of our farmers solve their own problems was printed last July. The supply of this bulletin has been completely exhausted and a reprint has just been made. Fully half the bulletins of the first edition went to the states other than Michigan and to foreign countries.

It would seem hardly necessary to spend much time in describing this method of irrigation. The most of you are already familiar with it. Briefly, however, the distribution consists of a canvas tube about 2½ in in diameter laid along the center of the row. The farther end of the tube is closed, and the water is pumped into the other end. The

[1]Paper presented before the Land Reclamation Division at the 28th annual meeting of the American Society of Agricultural Engineers, at Detroit, Mich., June 18-20, 1934.

[2]Research specialist in agricultural engineering, Michigan State College.

tube merely serves as a means of conveying and distributing the water quickly to the farther end of the row. In other words, it is a modified trench system of irrigation. The hose is an artificial trench built above ground through which the water seeps into the soil.

The use of the hose causes a more rapid movement of water to the farther end of the field and makes it possible to irrigate rows with small variations in elevation. In fact, water can be carried over knolls 4 or 5 ft high, but better distribution can be secured if the elevations are not more than 2 ft.

We have found that, if the hose is made up of different weights of canvas, better distribution will result and longer lines can be worked. Eight, 10, and 12-oz canvas are the weights commonly used. Lines as long as 700 ft have been operated successfully. Such lines are usually made up of about 250 ft each of 10 and 12-oz canvas and 250 ft of 8-oz, with 50 ft of old fire hose or heavy canvas hose next to the pipe line.

On a field nearly level or slightly up grade, the heavier canvas is used next to the pipe line. On fields with considerable fall away from the pipe line, it is sometimes necessary to reverse the order and put the heavy canvas at the lower end.

Most of the farmers in the state pump water directly from lakes or streams into a pipe line which extends along the high end of the field to be irrigated. In some cases no pipe line is necessary. A portable pumping unit is moved along the end of the field and the water pumped directly into the hose line.

This year a great many people, who do not live on a stream or lake, have become interested in irrigation and wells are being resorted to. We are making a study of this well problem in an endeavor to determine what is the best type of well and how deep it is practical to go for water.

One line of hose 660 ft long will require 50 gal of water per minute. If this line of hose is allowed to remain in a row of potatoes about 20 min, it will put on one inch of water. The one-hose line will cover an acre of potatoes with one inch of water in 10 hr. One man under favorable conditions can handle three 40-rod lines of hose and thus cover about three acres in 10 hr.

Moving the Hose in Row Crops Is a Comparatively Easy Matter

It is a comparatively easy matter to move the hose from one row to the next in low crops such as potatoes or strawberries. By means of a little roller, the hose can be moved from the wet row to the dry row as fast as a man can walk. A 40-rod line can be moved in about 3 min.

For high crops such as raspberries, orchards, etc., it is more difficult to move the hose. We have been working on a new kind of reel for these crops. The reel is laid flat and the hose merely pulled around it. Three hundred feet of hose when worked in two sections can be moved with this reel.

The average farmer with ten to fifteen acres of potatoes to irrigate usually invests from $300 to $500 in equipment. Some manage with less than this where the field is alongside a lake or creek, or where a tractor is used for power.

We have many cases where equipment is used that has not been properly selected for the purpose. Many power units are too large for the job, and therefore pipe lines which are too small, but considerable inefficiency is allowable on some of these emergency installations in order to save a crop.

The most of our pumping so far has been done with centrifugal pumps, although any type of pump with sufficient capacity can be used. Capacity is more important than pressure, although the pump should be able to lift water against the static head, overcome the pipe line friction, and have 10 to 12 lb additional pressure to cause the oozing in the hose line.

We have one orchard installation which was only completed about a week ago which is a little above the average for the state. In this case a 25-hp, three-phase motor is used for power connected to a two-stage centrifugal pump. About 2,000 ft of 5-in pipe line is used to convey the water to the orchard. The water is pumped from the St. Joseph River with a vertical lift of 85 ft and delivered at the rate of 300 gal per minute at the end of the pipe line. Two-inch nipples are welded into the pipe line every 80 ft. There are six distribution lines; each line is made up of 50 ft of second-hand fire hose and 500 ft of porous hose. This system will cover three acres with 2 in of water in 10 hr.

Most of our experimental work so far has been on potatoes, although we have done some fragmentary work on other crops such as strawberries, raspberries, truck crops, and orchards.

The Cost of Applying Water Is Dependent on Several Factors

Reports of 100 per cent increase on truck crops and small fruits are common. On potatoes our experimental plots show increases of from 50 to 150 bu per acre. Last year we had one farmer who secured an official yield of 420 bu per acre on a 15-acre field, and while we did not have a satisfactory check plot, the increase was probably 200 bu to the acre.

The cost of applying water by this method depends upon a number of factors. If the installation is designed to utilize the whole time of the operator, the cost will be lower per acre than on a small outfit.

The cost per acre-inch is made up of the following items:

Labor	$ .75 to $1.00
Overhead	.50 to .75
Power	.50 to 1.00
	$1.75 to $2.75

I hope, because I have dwelt at some length on the porous hose method of irrigation, that you have not got the impression that this is the only type which we recommend. The fact is we try to recommend the type that will fit the job most satisfactorily. In fact, we often suggest both the trench method and the porous hose method to be used in the same field. Wherever flooding can be used, it should be used. In a great many cases where a permanent system is desired, overhead irrigation will be found more satisfactory. In many cases porous hose can be used in combination with the overhead system, thus enabling the farmer to extend his irrigation over larger areas before he may be financially able to extend his overhead lines to cover this area.

In the further development of irrigation in Michigan I am sure that porous hose will do its part in solving irrigation problems and in creating in the minds of a great many farmers a consciousness of the possibilities in utilizing a great many of our numerous water supplies for their material benefit.

Sanitation in Relation to the Production of Farm Commodities[1]

DURING THE PAST year we have been interested primarily in the development of standard practices which relate to sanitation in the production of agricultural commodities. In this connection the A.S.A.E. subcommittee draws attention to the work of Professor H. B. Walker, a member of the committee, on public health standards for the construction of milk houses and milking barns. The results of this investigation have been published in mimeographed form as Agricultural Engineering Information Series No. 5 of the agricultural extension service of the University of California, as a contribution from the California agricultural experiment station, the state department of agriculture, and the California Association of Dairy and Milk Inspectors.

The standards presented constitute a minimum construction code for buildings that are to be used in the production of market milk and cream in California. They deal with the factors relating to the location, design, and construction of the buildings which either directly or indirectly influence the purity of the production.

We are of the opinion that cooperative studies of this character constitute a peculiar field in which rural sanitation should be developed. The chairman of the A.S.A.E. subcommittee traveled through about twenty states during the year and had intimate contact with the agricultural experiment station in each of those states in connection with the official examination of the work and expenditures under the provisions of the Hatch, Adams, and Purnell Acts. It became apparent during these visits that there should be closer cooperation by agricultural engineers with animal husbandry, dairy husbandry, poultry husbandry, veterinary, horticulture, and foods and nutrition departments of agricultural experiment stations in specific studies relating to rural health and rural sanitation.

The question of sanitation in the production of dairy commodities is rather well known to agricultural engineers. However, the danger to human beings of disease infection from dairy production animals from troubles such as contagious abortion, infectious sore throat, and other disorders, cannot be overlooked in the organization of studies in rural sanitation. It is known that bovine contagious abortion may produce undulant fever in human beings. Infected cows are known to excrete the organism in their milk. Presumably it is through this means that most of the danger of infection lies. However, the means of transmission between animals is not fully known, and it is not entirely established that milk is the only means of transmission to human beings. It is believed that more thorough cooperation between dairy husbandry specialists, agricultural engineers, and pathologists may clarify some of these questions and result in the planning and construction of stalls, drains, corrals, and the like, and in the control of the drainage from corrals in a manner which may materially improve the situation. In the same connection the transmission of infectious throat disease through milk may possibly be related to the manner of construction and use of milking machines. The Wisconsin agricultural experiment station particularly has thrown considerable light on the transmission of such diseases to human beings, and it is believed that a problem involving the cooperation of the agricultural engineer exists here also.

In animal production the dangerous disease of porcine contagious abortion which, according to available evidence, may produce a particularly dangerous type of undulant fever in some human beings is another outstanding example of where the agricultural engineer may cooperate with animal husbandry specialists and pathologists. The evidence indicates that the disease may be transmitted between animals and between animals and human beings by personal contact through the medium of skin abrasions. It would seem that cooperation by agricultural engineers with animal pathologists in connection with the clarifying of this situation might result in a safer and more methodical practice in the housing and isolation of infected animals, which would involve the development of special structures and environmental conditions.

Trichinosis in human beings resulting from the eating of improperly cooked pork from hogs infected with the trichina parasite, would also appear to be an important sanitation problem. The connection of the engineer with this problem may appear to be remote, but since it is a problem of sanitation, it seems that the engineer should be intimately acquainted with it in order to be ready to introduce any mechanical or sanitary engineering methods which the pathological and entomological studies may indicate as necessary or desirable.

The many diseases to which poultry is subjected, some of which apparently may be transmitted through the egg, offer considerable opportunity for constructive thought in connection with rural sanitation studies. The widely spread and highly variable disease known as "range paralysis" is one in which it would seem engineers should become interested. Nothing definite is known at present regarding the actual cause or causes of this disease of poultry. For the same reason, therefore, less is known regarding its means of transmission and means for its control. Whether it is dangerous to human beings or not is likewise unknown, but since it involves a problem of sanitation the engineer should be intimately acquainted with the work in animal husbandry and animal pathology which relates to it.

Numerous studies are in progress at various experiment stations of means of isolation and control of the disease in infected birds. These studies involve problems in the physics of air movement as well as in the development of proper structures, factors in which the engineer should be interested. Many diseases of this character call for isolation from the ground and testing of the different types of flooring and environmental conditions. Studies conducted at the Oklahoma station on the relation of the cleanliness of the air in poultry houses to the keeping qualities of eggs and their ultimate nutritive properties, draw attention to a problem in which engineers should be interested. The results of these studies showed that as the eggs were laid in various atmospheres, the surfaces of the shells were coated with varying amounts of dust. Apparently the greater amount of dust carried a proportionate number of

[1]The 1933-34 report of the A.S.A.E. subcommittee of the Joint Committee on Rural Sanitation sponsored by the American Society of Agricultural Engineers, the American Public Health Association, and the Conference of State Sanitary Engineers. The A.S.A.E. subcommittee consists of R. W. Trullinger (chairman), E. W. Lehmann, and H. B. Walker.

bacteria, and as the eggs became more dirty their keeping qualities and their ultimate nutritive qualities went steadily down. This suggests that the shell of an egg, which has been thought heretofore to be a hermetically sealed affair, is not as resistant to the attack of bacteria as has been previously thought. If the egg can be attacked through its shell by ordinary putrefactive bacteria, there would seem to be some possibility that it might also be attacked by disease bacteria. While these are perhaps somewhat muddled points of view, and would appear to be somewhat farfetched, it would appear that the engineer has a very definite sanitation responsibility in connection with poultry production.

The many factors of sanitation in the storage and keeping qualities of fruits and vegetables involve considerable cooperation already between the agricultural engineer and the horticulturist, which go further than to merely consider the development of the structures themselves. The factor of nutritive quality of vegetables, as affected by storage, is particularly important, this having been brought out, for example, by studies at the Montana station. The studies at the Colorado station on the canning of fruits and vegetables under high-altitude conditions, which brought out the extreme danger to human beings of such practices in connection with botulinus poisoning, is a typical matter which would appear to justify consideration by agricultural engineers. It was found in this particular case that, in the canning of many fruits and vegetables, the use of high-pressure cooking apparatus is necessary for the destruction of many of the pathogenic organisms and their spores. Here again the agricultural engineer interested in rural sanitation may become profitably engaged in the development of equipment which may be used for the proper processing of fruits and vegetables under such conditions.

We are impressed with the fact that the animal pathology department of the average agricultural experiment station is a good place for the agricultural engineer to offer his cooperation in studies of rural sanitation. So many serious diseases of animals and poultry are prevalent under farm conditions today that close cooperation with animal pathology departments seems quite desirable, especially when there is more than a little evidence to indicate that some of these diseases may either be transmitted to human beings in various forms or that they influence the quality of food products consumed by human beings in one way or another. Consultation with veterinary medical departments of several agricultural experiment stations indicates that cooperation with agricultural engineers in this connection would be a departure from present practice and would be subject to considerable scrutiny by the veterinarians themselves. Apparently it will be necessary for agricultural engineers not only to interest themselves in these matters but to prove their place in the study of the problems involved, particularly in the minds of the veterinarians themselves. We are impressed with the fact that animal pathology departments would be more than willing to cooperate if something of a worth-while cooperative character is brought to them by the engineers. They are already in this field of study, and it would seem, therefore, that the first move is up to the agricultural engineers.

Essentials of a Good Farm Fence Installation

BECAUSE of the extremely dry weather during the spring months this year, fences have been subjected to more than ordinary service. Farm animals, foraging farther and farther, have strained and damaged fences much more than in ordinary weather. We can therefore expect them to need considerable attention and repairs.

A legal fence, as defined in the Minnesota statutes, should have posts not more than one rod apart, and the wires should have at least 40 barbs to the rod. A fence of barbed wire should be constructed of not less than four barbed wires, the lower wire to be not less than 12 in or more than 16 in from the ground and the top wire to be not more than 48 in from the ground. A fence made of woven wire, should be not less than 32 in high, and should then have above it two barbed wires, the first not more than 4 in above the woven wire, and the second barbed wire not more than 8 in above the first barbed wire. The woven wire fences can also be 40 in or more in height, with one barbed wire not more than 4 in above the woven wire. For average conditions the most desirable spacing of barbed wires is to fasten the first wire 14 in from the ground and to space the other three wires at intervals of 11 in. This brings the wires at distance of 14, 25, 36, and 47 in above the ground.

Posts are usually spaced one rod apart, in permanent fences. This is a great advantage when measuring acreage. A mechanical pacer, taking three paces to the rod, is very convenient for locating positions of posts. Spacing at and near corners may need to be less than one rod. A distance of 11 ft for the first two rods is frequently used. This space can be measured with two steps of the mechanical pacer (which has a spread of 5½ ft).

Bracing of the corner posts should be very carefully and strongly made, as the corner post strength really determines the strength of the entire fence. The posts themselves are usually larger and stronger than line posts. Two types of bracing are in common use, one having a horizontal brace between the tops of the posts, and the other having a diagonal brace with its high end at the corner post. In each case, it is necessary to have diagonal wire bracing, the lower end being toward the fence corner. The wooden or steel bracing takes the compressive stress, while the wires are in tension. It is well to use both of these braces, in series, for a tight fence, although either brace alone might be sufficient for three-wire pasture fence corners or ends.

When wooden 4-in by 4-in braces are used, there is some advantage in using the horizontal type, as this keeps both ends away from the sod, where decay or rotting is liable to occur. Braces are sometimes made of steel pipe, or channels, which may have the advantages of strength and stiffness, as well as longer life.

To keep the corner posts from leaning or pulling up, short cross-planks can be fastened across the lower ends of the posts, and buried in the ground.

Wooden posts have been used largely in the past. They are usually very strong but do not always last long. Some of the most durable woods for this purpose are white cedar, white oak, and bur oak. A hot creosote or other good preservative treatment will increase the life of most all wooden posts by a number of years. The poorer post woods show a considerable gain in durability when so treated.

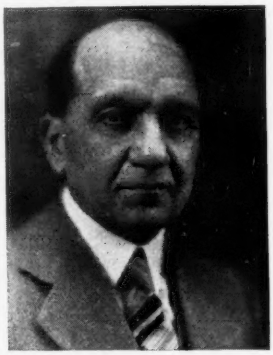
Steel posts of various shapes have been used more in recent years. They have the advantage of longer life than wooden posts, as well as being easier to drive and pull from the ground. However, some of the thinner ones are hardly strong enough, even when new, to withstand the onslaught of a husky farm animal, so care should be exercised in selecting steel posts of sufficient thickness and strength. The cost of steel posts is only a little more than that of good wooden posts.

Concrete posts are frequently used, especially for ends and corners of fences. They are very strong and durable when carefully made. A good concrete post must be made of a fairly rich mixture of concrete, and, of course, requires steel reinforcing.—L. W. NEUBAUER, agricultural engineer, University of Minnesota.

Athlete, Soldier, Scientist, Engineer

Bits from the biography of Colonel Oliver Brunner Zimmerman

EVEN his colleagues in the American Society of Agricultural Engineers, men who have enjoyed much personal association with him, can scarcely know the measure of his achievements nor the colorful variety of his experiences, for Col. Zimmerman seldom speaks in the first person. This sketch cannot be a complete biography, but is intended to reveal some of the personal and professional facts concerning him, and to satisfy some of the curiosity that must attend publication of his notable paper on wheel analysis.



O. B. ZIMMERMAN

Oliver Brunner Zimmerman is a native of Galena, Illinois, but during his elementary and secondary school life was a resident of Milwaukee, Wisconsin. Passing from the Milwaukee public schools to the University of Wisconsin, he was graduated in 1896 with the degree of bachelor of science in mechanical engineering. Four years later, after professional experience and study *in absentia,* the same university conferred on him the M.E. degree. Some forecast of his scholarly career appeared in his entering the University with a thousand-dollar scholarship from his home county.

From his graduation at the University until 1900, he was for a year instructor, then director, in manual training at Milwaukee West Division High School, covering a more technical and vocational curriculum than the term usually implies. The next two years he returned to the University as instructor in descriptive geometry and elementary machine design. The latter year (1902) he also pursued special studies in physical chemistry. From then to 1905 he was assistant professor of machine design, for two years bearing also the same title on the graduate faculty.

With the exception of the initial scholarship award, Mr. Zimmerman made his own way through the University. Yet he was able to "make" the track team for four straight years, winning his "W" as a sophomore. As a high school teacher he was also a volunteer athletic coach and director, his school winning two state championships and two second places during the four years. Spanning the years we find him a member of the Medinah Athletic Club and, in 1929, of its gymnasium committee.

The mental training and sportsmanship of the athlete are a mark of his professional life, seen in his instinctive fairness to colleagues, subordinates, and competitors; his equal capacity to take orders and to issue them; and his ability to take in good part the many resistances offered by commercial experience for rugged individualism in engineering. So, too, his persistent scholarship is seen in his pursuit of diverse courses of special study, including instruction during three years at the Milwaukee Art Institute.

His connection with industry began during his summer vacations, working as machine shop hand and drafting room retailer in a Milwaukee factory; assisting design of electrical power transmission system for an Ohio machine tool works; and as draftsman, calculator, and designer with the Western Electric Company. After a short period with a Milwaukee firm of machinists and founders, his next industrial connection marked his entry into the farm equipment industry.

This was the Hart-Parr Company, of Charles City, Iowa, which laid claim to being the founders of the tractor industry. During his three years there he progressed rapidly from draftsman through a variety of duties to design and development of engines, fuel work, plant equipment design, factory building, and even bridge and sewer design for the city.

Then came two years with the M. Rumely Company at the height of its expansion. Again he worked on tractor design (the famous OilPull) and on the buildings and equipment for its manufacture, including machine shops, test and auxiliary boiler plant, foundry, pattern shop and storage, power plant, and miscellaneous construction. This construction, approaching a half-million dollars in amount, was engineered and supervised at a cost of less than two per cent.

In October, 1911, after a few months in work mainly structural, Mr. Zimmerman joined the engineering staff of the International Harvester Company of Chicago where, with the exception of his war service, he was to serve continuously for more than twenty years. In North America he worked on every phase of tractor development, from the fundamentals of fuels to sales technique, and from Texas to the Canadian prairie provinces, including the historic Winnipeg contests. Abroad he was advisory engineer to the European sales organization and the four European factories. His researches and field engineering took him to England, France, Germany, Italy, Hungary, Russia, and North Africa.

In October, 1915, long before the United States entered the World War, he volunteered for service in the Engineer Officers Reserve Corps, having been a second lieutenant in his university battalion. Early in 1917 he was called and commissioned Captain of Engineers, assigned to duty in Washington shortly after the declaration of war, and in October was advanced to the rank of major. He was slated for a lieutenant-colonelcy when the armistice occurred, and subsequently was assigned this rank in the Officers Reserve Corps.

At first in charge of the Mechanical Civil Equipment Division and later of the Research and Development Division, his myriad duties defy description here. The first division, with an engineer officer personnel of 47 or less, handled all the problems of design, selection, and purchase of some 400 million dollars worth of material. A single example of the work done by the research group, comprising up to 38 engineer officers, was the photographic developing agent called metol, desperately needed by the signal corps. Normally it was obtained from Germany at about six or seven dollars a pound. Early in the war the price advanced to $200, and seven months of effort had failed to produce a duplicate. Assigned to Major Zimmerman's research chemists, the formula was solved in seventeen hours.

During these hectic war days he also served on the National Screw Thread Commission, created by Congress to bring order out of chaos in dimensions, pitches, tolerances, etc., used by hundreds of screw manufacturers. One of his reports ran a hundred pages, and was all real data on screws. He also was a member and leading spirit in the Board of Review to check and approve all army purchases.

In 1919 the Pennsylvania Military College, deemed second only to West Point, bestowed honorary degrees in recognition of war achievement. To the army engineer corps went three of these degrees. One recipient was the Chief of Engineers, Major-General Wm. M. Black, another was Brigadier-General W. H. Rose, and the third was Major of Engineers O. B. Zimmerman.

Returning after the war to the Harvester company, he embarked on a far-sighted program of standardization and improvement of specifications on materials, designs of machine elements, etc., for the sixteen factories of the company. This involved working with the materials and standards committees and engineering board of his company, and with a wide range of committees and subcommittees in various technical societies, industrial associations, etc., including the American Society for Testing Materials and our own Society.

In 1928 was formed a wheel committee of which Col. Zimmerman was chairman and inspiring genius. His paper elsewhere in these pages is a part of the fruition of those labors, which completed his long connection with the International Harvester Company. At present he is engaged in consulting mechanical and agricultural engineering, and has offices with Johnson and Company, 333 North Michigan Avenue, Chicago.

A Technical Analysis of the Agricultural Implement Type of Spoked Wheels[1]

By Oliver B. Zimmerman[2]

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THIS TECHNICAL development is the result of a desire to supply engineers with a logical method of approach to wheel design. It is also intended to enable the designer to determine quickly and to visualize what the stress values and variations are in the wheel form of structure when the wheel is stationary, when it is operating under normal loads. It must also foretell where to emphasize the strength to anticipate emergency stresses.

After much search of technical literature and textbooks on mechanics, it was evident that this source did not reveal any presentation of value on the wheel. The few articles in the bibliography reviewed were found to be of popular type and interest. The importance of a clear solution from a machine design standpoint forced attention to the problem, with the results set forth in this paper.

The first constructive developments were secured in early October 1929, at which time the method of approach by means of an interior polygon analysis and a dispersion and concentration of forces through graphics opened a solution. The moment and trigonometric solutions followed. Both are presented in this paper.

The development starts with a true coplanar radial-spoked wheel subjected first to a vertical load, then successively sidethrust, torsion, and pivoting strains. These coplanar stresses are developed later into space relations and are followed by modification from radial spokes to other forms. The simpler implement types can later be resolved readily into the required high-speed automotive types. (Coplanar wheels are to be construed in radial loading as those whose *spoke cone ranks* do not vary more than 7½ deg either side of a true radial plane through mid-hub, or which have an included angle of 15 deg and are near centerplane.)

Definition of Wheels

A perfect wheel is a round machine unit which, acting about an axle, is designed to function as a friction-reducing, load-carrying, or power transmitting device without noticeable elastic distortion.

Implement, road making, and tractor wheels are to be considered in this analysis as being those typical of a class which are built-up structures. Usually they are made of steel and gray iron. They are such as operate under heavy to light loads upon loose to hard ground, necessitating considerable area of contact to meet these conditions. The rotation is slow, being 25 to 75 revolutions per minute when travelling up to five miles per hour. There is much unsprung load brought to the hub and spread from the spokes to the tire and to the ground. The ground contact of plain tired wheels may be that of a bare line across the tire up to arch contact between a pair of spokes or even beyond. The usual wide solid tires, spokes, and hubs are at times subject to suddenly developed eccentric loads of noticeable proportions.

Historical Reference[3]

Wheels in a crude form were used by man long before recorded history. This takes us back of 5000 B.C., to which date wheels are readily traced. One authoritative record of rock drawings seems to date as far back as 20,000 years ago. We can only speculate, therefore, as to their origin and earliest use, since at that time (5000 B.C.) wheels were already in hazardous use on chariots and wagons for war purposes, or in such gentle use as ceremonials and pageants. A few were used for transporting big loads.

While any indication as to how the wheel came into existence is pure speculation, it would seem that the prototype of the wheel must have started accidentally as wood rollers, for in all probability as primitive man, for urgent reasons, was moving or dragging a stone or fallen log, he noted that it moved more easily as it passed over a fallen round limb. He may have slipped on such a limb, thus being jarred into a realization of its use as a roller. A vague idea of its usefulness may thus have started. By a gradual increase in diameter and shortening of length the wheel probably came into purposeful use.

A rotted hole through the center of these narrowed sections might have suggested the use of the dead axle. This wobbly combination initiated the cart rim sectors, and some thoughtful primitive doubtless developed the live-axle idea with its wheels turning in crude bearings as distinguished from the wobbly wheels and dead axle. Slab boards were perhaps next used to hold cracked log sections together. These later evolved into rim sectors.

Considerable evidence of the foregoing is shown in ancient illustrations painted on pottery, vases, wall decorations, low reliefs, or on miniature toys, bronze tablets, coins, and the like. Even today in Portugal, Spain, China, India, and other backward countries, we find existing and in use carts with wheels of these primitive types.

The step from the rough cart to the chariot wheel was a marked one. Ancient artisans of the Egyptians, Assyrians, Greeks, and Romans give us such records. Excavations in the royal cemetery of Ur and the operations at Kish carry us back to 3500 B.C. with certainty. There wheels and live axles were used and were fairly well developed for those days. Trailing the war chariot back we hear of the wild Nomad hordes of the East coming to Babylonia about the time of King Hammerabi (2100 B.C.) during the first Babylonian empire. These nomads brought with them many chariots which aided materially in their raidings. They were exactors of tribute according to Wells, but left to their subjects their type of development of the wheel.

In the Grecian period, from 900 to 300 B.C., we hear of and find many characteristic illustrations of chariots used in war, ceremonials, parades, and races. In exterior design

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[1]Paper presented before the Power and Machinery Division at the 28th annual meeting of the American Society of Agricultural Engineers at Detroit, Michigan, June 18-20, 1934. First of a series of papers dealing with the wheel and other machine elements.

[2]Consulting mechanical and agricultural engineer. Formerly assistant to the manager, engineering department, also supervisor of materials and standards, and chairman of the wheel committee, International Harvester Company.

[3]A more complete review of the history of the wheel is in process of preparation by the author.

[4]Patents applied for to date assigned to International Harvester Company.

and finish they became most decorative with their plated metal, but as useful strong objects they were crude. Some wheels were also highly carved and colored. Their structural features were geometrically correct for these purposes, as viewed in the light of nineteenth century wagon and buggy wheel construction.

The four-wheel wagon apparently came from ancient Babylonia about 5000 B.C. and appeared in Greece about 600 B.C. It is also mentioned in biblical history, in Exodus, but that wagon was not much used for human transport due to its rough riding qualities. There were no springs and plenty of bad roads. The horse, the ass, and the ox were far more comfortable as a carrier for humans on their journeys.

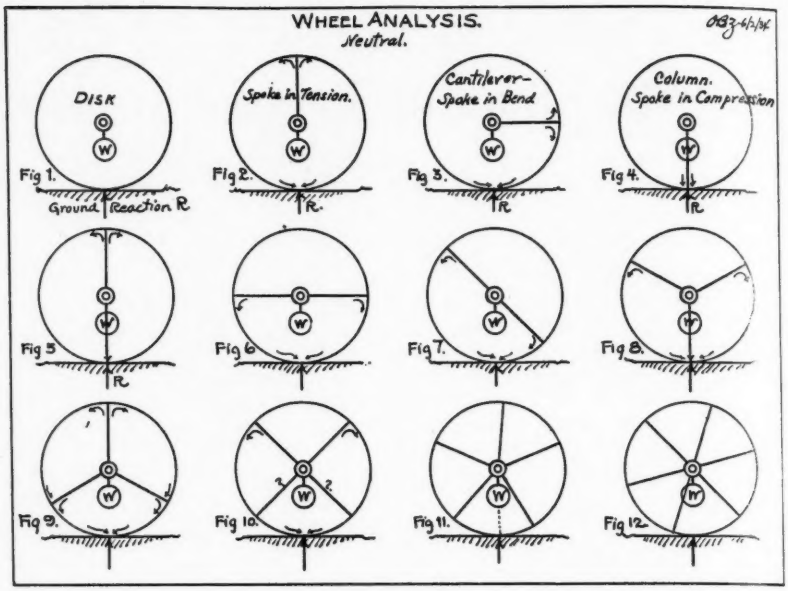
To overcome wear and to hold things together, the metal tire and binding plates were introduced to replace wooden pins, copper nails, and various lacings; likewise the bronze and iron bushing appeared as the hub. Then wagon development ceased until English coaches, and more especially our American modern wagon and buggy types, were designed.

The bicycle makers and the automotive engineers gradually replaced the wooden spokes, rim, and hub with steel. Wooden spokes in automobiles, then, are historically the last utilization of this ancient material.

Metal wheels of the current agricultural implement types seem to date back not much over one hundred years. This type of iron and steel wheel came about due to a desire for weight reductions, to resist the weather, to reduce repair, to insure greater stability, and to make use of available new materials; hence our many cast wheels, formed steel parts cast together, riveted construction, and finally the electric welded wheels. Modern built-up wheels—cast iron and steel combinations and similar types—have gone through many years of design effort, yet since modern textbooks covering machine and product design contain such meager information on the wheel as to be practically worthless technically, it is no wonder that we have the variations now prevalent. An intensive search made in 1929-30 by several well-known librarians, by archeologists, and by the author has disclosed to date nothing of value relative to the technical analysis of stresses and strains in wheels.

It must be recognized then from the very start that the vast majority of wheels of today were not engineered in a technical sense. Although designs arrived at by a process of trial, they nevertheless represent a very fair suitability to their purpose. Just as a review of the ancient wheels discloses the emphasis an artisan and his copyists believed in as to strength of tire, arrangement of spokes, hub, or shape, so today we find similar personal preferences controlling designs rather than correct theory.

Viewed from their specific applications, these empirically or practically developed wheels have incorporated in them not only the ability of taking regular load strains, but they resist as well the many unexpected or accidental and undefined stresses common to their use; hence we can and must use these structures as a good guide when ascertaining characteristics for new wheels which are to be substituted for them for a particular class of work. This does not mean, however, that current wheels which satisfy these conditions are, by any means, representative of correct distribution of material, weight, or strength or method of manufacture. This will be readily proved by comparative tests later in this discussion.



FIGS. 1 TO 12

From the Year 1930 On

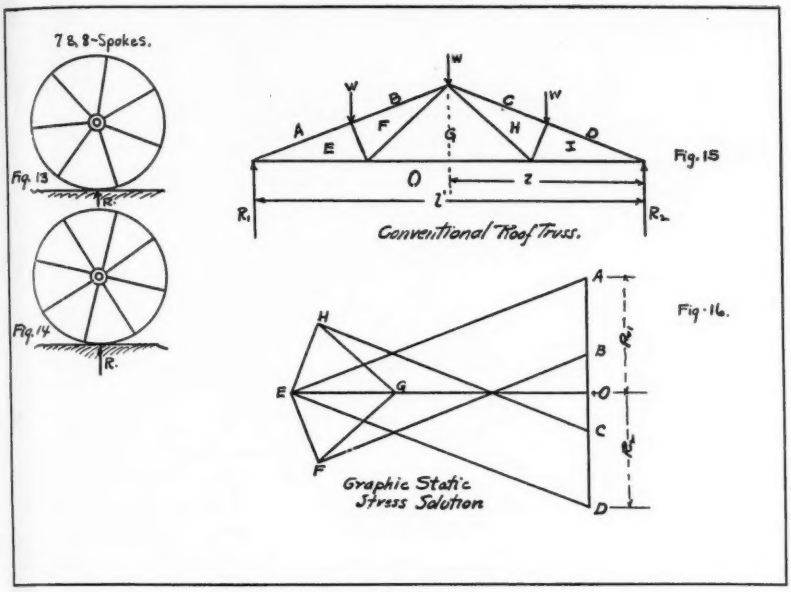
A numerous variety of wheels naturally resulted from the foregoing specific development, yet it is certain that there are common underlying fundamental principles covering the variations in stresses which operate. These fundamentals will be found to be the same in all wheels, which are geometrically alike, whatever their shape or material. These stresses may be sought by experiment, or they may be reasoned out.

The objective of this research analysis is, then, to arrive at a simple and practical method of determining the nature of, the magnitude and direction of, stresses developed in an elemental wheel structure when used under load. Further, it is desired to analyze and visualize the simple, or any combination of the possible major stresses, namely, vertical load, sidethrust, torsion, and pivot, whether they be static or rolling fatigue stresses; also what the effects are when there are intentionally impressed stresses produced in manufacture acting along with stresses produced by load.

Inasmuch as this is a very involved problem with many variable angles to develop, it will be seen to be one which is impossible of conjecture unless it be systematically, painstakingly, and analytically solved. It is necessary to make certain general assumptions and evolve from these into the ramifications. By this method we shall finally have a logical overall analysis which will enable us to meet the problem in line with known field requirements, costs and practice in manufacture, and the desirable materials used.

Technical Approach

We have the difficult problem of starting from scratch to develop the nature and effect of wheel strains in what appears to be a simple structure.



FIGS. 13 TO 16

Owing to the fact that the wheel is to a large degree a free body, yet constrained to one plane, this apparent simplicity is not true. Since the built-up wheel is a complex structure, however, we can use our knowledge of static built-up structures to guide us in our approach to an analysis.

For our immediate interest a wheel is most commonly a load-carrying device or machine element arranged to lessen the friction of transportation of loads carried. Inasmuch as it is a "structure," whatever the materials of construction may be, the loads and ground reaction and the strains and stresses set up in the wheel sum up the same for a given load, but the make-up, the arrangement, or the design of the structure affects the amount and direction of these stresses and strains. Hence the quality and quantity of material incorporated within this structure and the method of connecting part to part to meet these conditions must be very carefully studied.

Likewise the friction of transportation is dependent upon the wheel proportions as well as the nature and the composition of the surface upon which the load is normally carried. The design of tire, axle, spokes, hubs, bearings, *must therefore be dependent factors of the stresses and strains, material used, and the field conditions* under which it is intended to operate.

Since the commercial wheel of today is a built-up structure, it is necessary to evolve some simple means of knowing how to find these stresses and strains under normal working conditions, just as we proceed when designing a static structure, such as a roof truss, bridge, or similar static structural unit. To these values we can then add the practical specific requirements of its mobile use. We must meet these requirements with a satisfactory cost and with a practical minimum of material.

We may group certain sets of static and fatigue strains of a simple carrying or driving wheel rolling under load as follows:

1 Those strains and stresses due to bearing the *load* between the axle and ground; we shall call these *the radial load stresses.*

2 Strains due to *sidethrust,* or those lengthwise of the axle, such as downhill thrust, angular lug thrust reactions, and *skidding* out of line with wheel plane; we shall call these *sidethrust stresses.*

3 Strains due to hub and axle friction, brake action, and power transmission create *torsion.* We shall call these *torsional stresses.*

4 Strains due to field operation such as true slow spinning or rapidly turning away from a straight path in a short distance of advance. We call these *pivotal stresses.*

5 Those due to *intentional impressed tension* or *compression* spoke strains specified by the designer of the wheel members. We shall call these *prestraining stresses.*

6 *Suddenly applied loads;* strains produced by the load during usual operation. We shall call these *impact stresses.*

7 *Accidental strains.*

With this varied and complicated picture in mind, let us see what can be done to organize the approach into useful lines. We shall endeavor to answer the question, *"What goes on in a wheel when it turns around under load?"*

Suppose we begin a study of this structure along the following lines to see how far we can go by ordinary reasoning.

In Fig. 1 we have the simplest condition of a wheel with no initial internal stresses carrying a constant vertical load of 1000 lb ($= W$) on the axle. The reaction on the level ground will be 1000 lb plus the wheel weight which for sake of simplicity we shall temporarily neglect. How this load reaches the ground from the axle is determined by the designer when he substitutes various tires, a disk, or places spokes between the hub and the tire.

Assuming practically a rigid construction so as not to have to deal with evident elastic distortion conditions, let us develop the ideas of a wheel where all forces are acting in one plane, or, as stated, up to a 15-deg included angle. This is a coplanar structure. Later we shall spread out into space relations.

In Fig. 2, if we insert one spoke only between the hub and tire, it is obvious the strain in this spoke will be as shown in this figure, that is, one of pure tension. The tire then is in a complex arched beam because the load must reach the ground by traveling up the spoke and divide itself to right and left to get to R on the ground.

In Fig. 3 there is no doubt as to this one spoke acting as a cantilever. In any intermediate position between Fig. 2 and Fig. 4, a combination of tension or compression and bend results. The tire again carries the strain to R.

In Fig. 4 there is no doubt as to the spoke being in compression; the tire is entirely out of action except at the base point.

In Fig. 5 we have a two-spoke wheel. We must be content to argue at this point that the major strain is similar to Fig. 4, with a faint load perhaps rising to the tire and around to R, because of the elastic condition of the two tire arches. Without proof, the amount is conjecture.

Fig. 6 shows the two spokes and hub as being part of a beam, while the upper half tire arch is practically neutral.

In Fig. 7 the wheel divides the load around to R symmetrically, but the arch deflections are evidently different owing to their lengths under this setting.

Fig. 8 shows a division of the stresses with the major load on the vertical spoke, while a part of it travels to each rim arch and to ground. Complexity has entered to a considerable degree, and we are less certain of our casual observation or reasoning; hence we must resort to well-defined and established certainties to tell us what is going on.

In Fig. 9 we cannot even guess with remote accuracy as to what happens in stress distribution. In the same manner we may review Figs. 10, 11, 12, 13, and 14.

It is obvious each set-up of increasing spoke disposition needs a special solution, but generally speaking rigidity and the lesser mass of material to meet the needs seem apparent with the increase of numbers of spokes.

That the spoke acts as a strut, as part of a beam, as a compression member, or as a tension member in a neutral wheel, seems clear; also that the tire arches are either sections of a continuous beam, usually in compression, or they are arched columns between spoke ends eccentrically loaded. Further, as the number of spokes increases the tire arches become shorter if the spokes properly support them.

Since, in this one-plane discussion, the axle, load, and ground reaction are all normally in one vertical gravity line, we find it impossible to analyze the strains direct; so we must devise a means of getting around this condition. The major stress line will tilt in the direction of travel according to the magnitude of the rolling resistance, but it nevertheless remains a directional line betwen axle and ground reaction.

Graphic Statics

Diverting for a moment to note the methods used in solving roof trusses, bridges, and buildings, we know that problems of this type are solved by the application of graphic statics and moments, which procedure enables engineers to work out their problems fast and with a high degree of practical accuracy.

Fig. 15 illustrates a simple roof truss with applied loads w, w, $w = W$; and wall reaction R_1 and R_2. The regular method of ascertaining the several stresses in the members is very well known and results in the stress analytical diagram shown in Fig. 16, which, interpreted to scale, gives us the relative stress value of a neutral structure loaded as indicated. For this development many good texts on graphic statics are available.

In a wheel structure, however, we must deviate somewhat from the usual approach of graphic statics, only so far as the start is concerned, following which the analysis is very similar.

For the sake of simplicity we will use a five and a six-spoke wheel in order to develop the principles. Let Fig. 17 be such a wheel with the load W acting so as to present a mid-arch tire contact with the ground.

Since stresses act through the several joints, let us inscribe the pentagon as shown between tire-to-spoke joints to aid in the analysis. For the moment it is well to consider the wheel as built of parts pin-jointed together; this is warranted to care for punched holes for lugs, for wear and tear, and for irregularities in manufacture. Stresses act between joints on air lines, so to speak. If we could interpose a direct straight-line member, the load between those points would be as simple as is possible. If, however, for good reasons, we have to modify any member, so that resisting material lies off the direct line, a bending moment results and must be cared for along with the compression or tension unit stress. So in this case the tire arches are disposed so that, if they are off of the direct lines, we can solve the stresses as of the inscribed polygonal structure first, then use these data for the modified complete solution.

For this purpose, let us use the usual graphic static lettering method of A, B, C, D, and E to represent the spaces between spokes, and I or other letters as the space outside of the polygon. Then the members or stress lines may be lettered as shown by the lines AB, BC, BI, CD, etc., and the joints 1, 2, etc., as shown in Fig. 17.

While the wheel usually rests on the assumed rigid ground at midarch, let us assume for the moment that we permit it to contact only at the two joints where R_1 and R_2 together represent the reactions equal to W, the load. Now we are ready to determine the stresses.

Analytical Graphic and Trigonometric Solution of Wheel Members Under Stress

(NOTE: The following original solution, for the determination of wheel stresses, was made in 1929 by the author, and forms the basis upon which a comprehensive analysis of all other stresses—coplanar and space stresses—can be made.)

Problem: To determine the value of stresses in wheel members in terms of the known values of load W, number of spokes n, and the functions of angles lying between the spoke elements at the hub and between the spokes and the inscribed polygon formed by joining the outer spoke ends. Pin-jointed connections are assumed.

Development of Force Polygon. Using Fig. 17 as a basis, produce Fig. 18 as follows: Lay off $R_1 + R_2 = W$ to

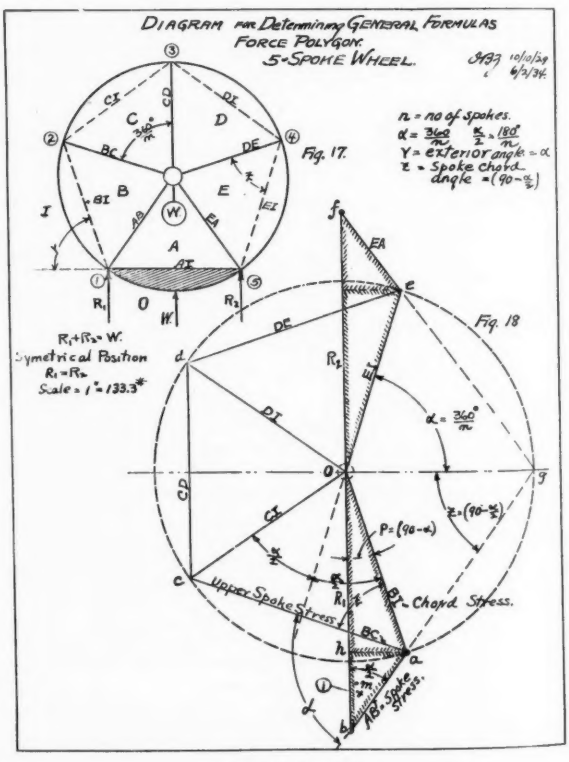


FIG. 17 AND 18

a known scale, or line "bof". Since $R_1 = R_2$ in a symmetrical figure setting, we establish point "o" at its center.

On Fig. 17, note chord 1-2 as chord of tire arch between the same points, which chord represents the direction of force through space between these points; hence, for the time being we will consider the chord *BI*, substitute for the arch, and make deductions and corrections later.

The arch 1-5, Fig. 17, can be considered as a beam carrying the structure and load. At point 1 we have the vertical force R_1 resisted by two downward forces *BI* and *AB* taken in order, clockwise about point 1. (In Figs. 19 and 20 the order of stress is counterclockwise.) Hence in Fig. 18 we lay out $R_1 = bo$; from "o" we lay out "oa" in direction of *BI* of Fig. 17, and from "b" we lay out "ba" in direction parallel to that of *AB* of Fig. 17 closing triangle 1. Then *AB* and *BI* represent in magnitude and direction the value of spoke stress and chord stress respectively for this symmetrical position.

Continuing we pass to juncture 2, Fig. 17, where the three directional strains meet — *BI*, *CI*, and *BC* — which again in Fig. 18 are developed in triangle "aoc".

Triangles 3, 4, and 5 complete the diagram.

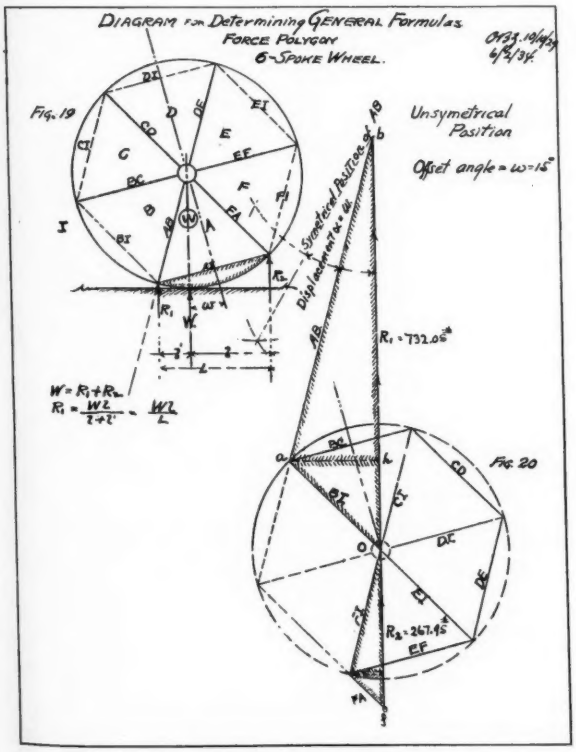
Since a trigonometric solution can now be made for all positions, we will first carry through this symmetrical one and later introduce the more complicated one of the unsymmetrical layout.

Following the trigonometry of Fig. 18, we have

m = angle between R_1 and line *AB*
p = angle between R_1 and line *BI*

We wish to determine three prime stress values, those of AB, BI, and BC in terms of W. These are, respectively,

1 The stress in the two lower spokes, *AB* and *EA* (Fig. 17)



FIGS. 19 AND 20

2 The stress along the interior polygon—*BI*, *CI*, *DI*, *EI*

3 The stress in other spokes than the two lower ones—*BC*, *CD*, *DE*, etc.

In Fig. 18 angle $p = (90 - \alpha) = (90 - 360/n)$.

In the triangle "oab" the included angle "oac" $= z$, and angle "cab" = exterior angle $= \alpha$; therefore, we can find m as follows:

$$m = 180 - (p + z + \alpha)$$
$$= 180 - [(90 - \alpha) + (\frac{180 - \alpha}{2}) + \alpha]$$
$$= 180 - 90 + \alpha - \frac{180 - \alpha}{2} - \alpha$$
$$= 90 + \alpha - \frac{180 - \alpha}{2} - \alpha$$
$$= 90 + \alpha - 90 + \alpha/2 - \alpha$$
$$= \alpha/2$$

Trigonometric Formulas for Wheels

Problem: To determine the three prime values, those of *AB*, *BI*, and *BC*, in terms of W and the center angles, $\alpha = 360/n$

(a) Stress in the lower spokes *AB* and *EA* (Fig. 17)

(b) Stress in wheel between adjacent spoke-to-tire connections, *BI*, *CI*, etc.

(c) Stress in spokes other than *AB* and *EA*, or as shown *BC*, *CD*, etc.

1. The Symmetrical Position (Figs. 17 and 18)

$$R_1 = AB \cos \alpha/2 + BI \cos (90 - \alpha) \quad [1]$$

Also $AB \sin \alpha/2 = BI \sin (90 - \alpha) = BI \cos \alpha$ [2]

$$\therefore \quad AB = \frac{BI \cos \alpha}{\sin \alpha/2}, \text{ and } BI = \frac{AB \sin \alpha/2}{\cos \alpha} \quad [3]$$

Substituting equation 3 in equation 1

$$R = AB (\cos \alpha/2 + \frac{\sin \alpha/2}{\cos \alpha} \sin \alpha)$$
$$= \frac{AB}{\cos \alpha} (\cos \alpha \cos \alpha/2 + \sin \alpha/2 \sin \alpha)$$
$$= \frac{AB}{\cos \alpha} \cos \alpha/2$$

Lower spoke stress is therefore

$$AB = W/2 \frac{\cos \alpha}{\cos \alpha/2} \quad [4]$$

Substituting equation 4 in equation 1

$$R_1 = BI (\frac{\cos \alpha}{\sin \alpha/2} \cos \alpha/2 + \sin \alpha)$$
$$= \frac{BI}{\sin \alpha/2} (\cos \alpha \cos \alpha/2 + \sin \alpha/2 \sin \alpha)$$
$$= \frac{BI}{\sin \alpha/2} \cos \alpha/2 = \frac{BI}{\tan \alpha/2}$$

The chord stress between spokes

$BI = R_1 \tan \alpha/2$ or $= W/2 \tan \alpha/2$ [5]

$$BC = 2\,BI \sin \alpha/2 = 2\,R_1 \sin \alpha/2 \cdot \tan \alpha/2$$
$$= W \sin \alpha/2 \cdot \tan \alpha/2 \quad [6]$$

Use equation 4 for AB or lower spokes; equation 5 for chord stress, and equation 6 for upper spoke stress—all in symmetrical position.

II. The Unsymmetrical Position (Figs. 19 and 20)

(Rotated ω deg from symmetry)

$$R_1 = AB \cos(\alpha/2 - \omega) + BI \cos(90^\circ - \alpha + \omega) \quad [7]$$

$$\text{also } \frac{AB}{\sin(90 - \alpha + \omega)} = \frac{BI}{\sin(\alpha/2 - \omega)} \quad [8]$$

$$\therefore \quad BI = \frac{AB \sin(\alpha/2 - \omega)}{\sin(90 - \alpha + \omega)}$$

$$= \frac{AB \sin(\alpha/2 - \omega)}{\cos(\alpha - \omega)} \quad [9]$$

Substituting in equation 7

$$R_1 = AB \left[\cos(\alpha/2 - \omega) + \frac{\sin(\alpha/2 - \omega)}{\cos(\alpha - \omega)} \sin(\alpha - \omega)\right]$$

$$= \frac{AB}{\cos(\alpha - \omega)} [\cos(\alpha/2 - \omega) \cos(\alpha - \omega) + \sin(\alpha/2 - \omega) \sin(\alpha - \omega)]$$

$$= \frac{AB}{\cos(\alpha - \omega)} \text{ (cosine of difference of two angles*)}$$

$$= \frac{AB}{\cos(\alpha - \omega)} \cos \alpha/2 \quad [10]$$

$$\text{or } AB = \frac{R_1 \cos(\alpha - \omega)}{\cos \alpha/2} = \text{Lower spoke stress} \quad [11]$$

From equation 8

$$AB = \frac{BI \cos(\alpha - \omega)}{\sin(\alpha/2 - \omega)}$$

Substituting in equation 7

$$R_1 = BI \left[\frac{\cos(\alpha - \omega)}{\sin(\alpha/2 - \omega)} \times \cos(\alpha/2 - \omega) + \sin(\alpha - \omega)\right]$$

$$= \frac{BI}{\sin(\alpha/2 - \omega)} \times [\cos(\alpha - \omega) \cos(\alpha/2 - \omega) + \sin(\alpha - \omega) \sin(\alpha/2 - \omega)]$$

$$= \frac{BI}{\sin(\alpha/2 - \omega)} \cos \alpha/2$$

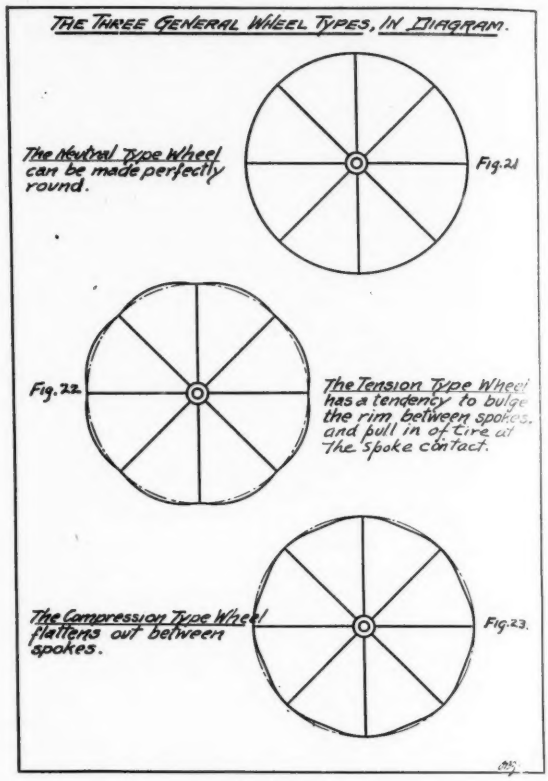
∴ The chord stress is

$$BI = R_1 \frac{\sin(\alpha/2 - \omega)}{\cos \alpha/2} \quad [12]$$

and the upper spoke stress is

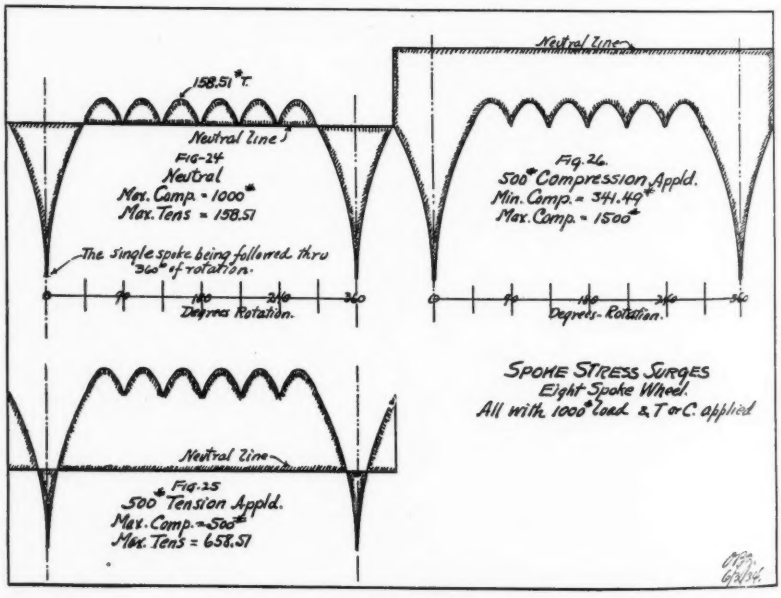
$$BC = 2\,BI \sin \alpha/2 = 2\,R_1 \sin(\alpha/2 - \omega) \tan \alpha/2 \quad [13]$$

*Since $(\cos[(\alpha - \omega) - (\alpha/2 - \omega)]) = (\cos \alpha/2)$


THE THREE GENERAL WHEEL TYPES, IN DIAGRAM.
The Neutral Type Wheel can be made perfectly round.
Fig. 21
Fig. 22.
The Tension Type Wheel has a tendency to bulge the rim between spokes, and pull in of tire at the spoke contact.
The Compression Type Wheel flattens out between spokes.
Fig. 23.

FIGS. 21 TO 23

In order to make practical use of this approach, we have adopted the wheel structure as that of an inscribed polygon; but since we need the circular shape to minimize the successive variations in the lifting of the load as it rolls along, we must replace the chord lines with circular arches. This does not change the air-line stresses.



FIGS. 24 TO 26

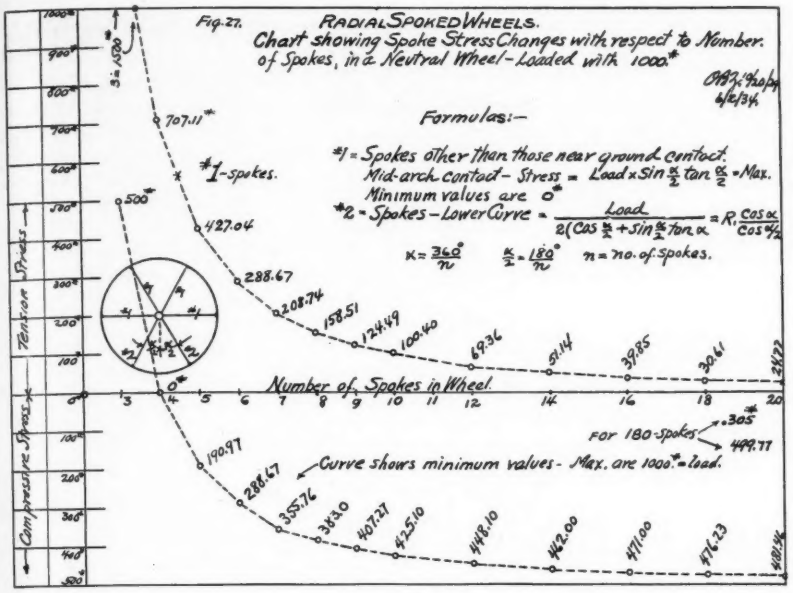


FIG. 27

The ideal wheel is a perfect circle, with tire and hub center concentric, and all parts of such stiffness normally as will make elastic distortion negligible in its effect under load.

We can build wheels in one of three dominant ways, classifying them according to the nature of the stress condition in the spokes:

1 Neutral type, that in which, when the wheel lies on its side, unstrained by load, the entire wheel taken part by part is without strain (Fig. 21).

2. Tension type, wherein we create tension stresses within the spokes of the wheel, whether intentionally so or as the net result of the process of manufacture to gain certain advantages (Fig. 22)

3 Compression type, wherein we create a shrinkage of the tire to hold all parts together (Fig. 23).

It is obvious that the tendency of the tension and compression types is to distort the tire, hub, or spokes, according to the relative weakness of the design, if the stresses impressed are sufficient to cause a give or relief to that extent.

It is therefore very important to deduce not only the correct choice of type for the purpose, but to know the correct measure or ideal stress to produce in the wheel structure, if we are to attain the maximum engineering good out of the material.

Taking the neutral wheel first, let us diagram a graphical dynamical curve, indicating the nature of the surges of

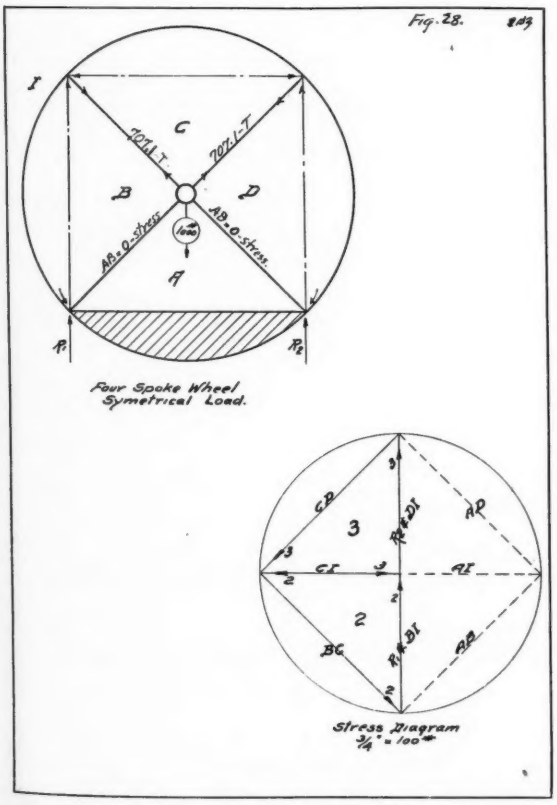


FIG. 28

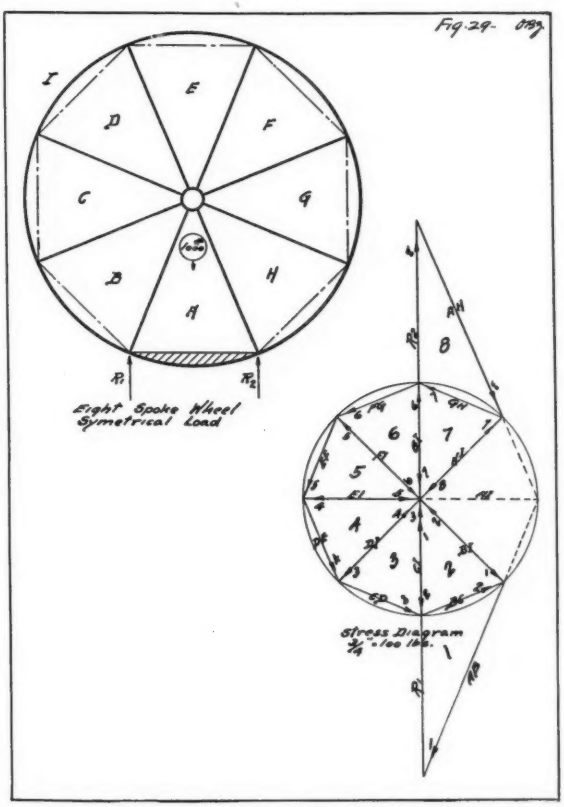


FIG. 29

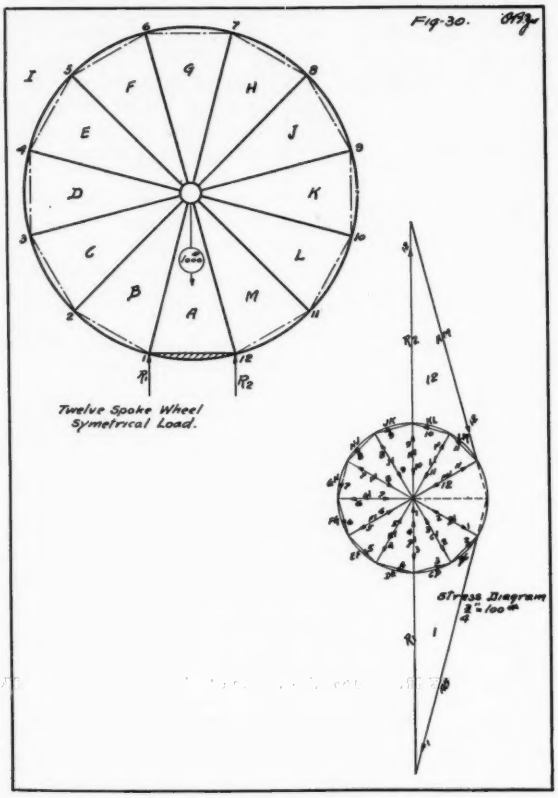


FIG. 30

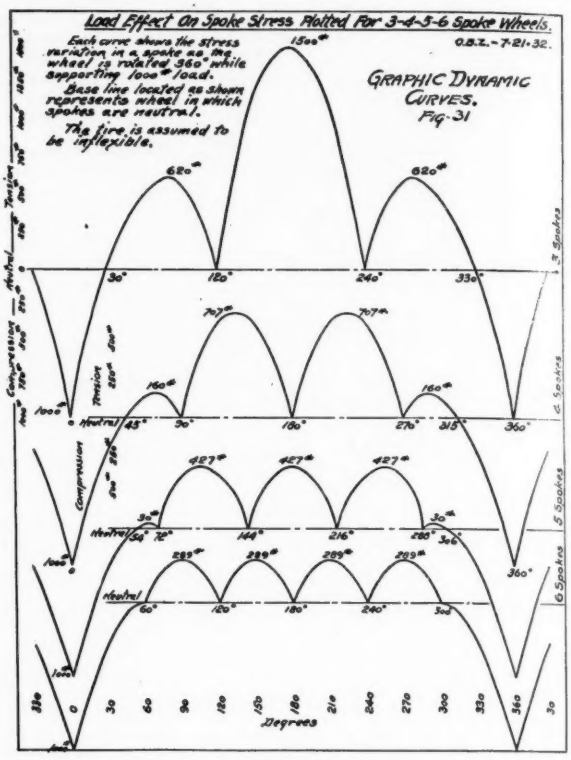


FIG. 31

pure spoke loading (Fig. 24). Imagine a wheel rolling under load on a level, hard surface at constant speed, and let us pick out one spoke to follow through a complete revolution. Start with the lower vertical spoke, and use the given formulas developed for *AB*—the lower spoke—from which we find either graphically or by formula that the full load travels from the axle to the ground, leaving the rest of the wheel with no added load stress. The 1000-lb load used is taken to facilitate our understanding of seeing values in percentages.

As the wheel revolves to the reader's right, the tire arch contact shifts the load from the first point on to two spokes (R_1 and R_3), and number 2 spoke position soon takes up the entire load.

Just how this load changes is shown clearly in detail in the diagram. It shows the 1000-lb load decrease to zero while the advance is through the contact arc. Then it passes on successively into tension (formula for *BC*); comes to neutral; and then in tension again, as many times as the number of spokes as the wheel may have less two, and finally completes its cycle, the load increasing to 1000 lb compression. These fluxes of tension and compression are of a definite pattern, but their magnitudes are modified by irregularities of road surface, by inertia conditions, etc. But in the simple form they repeat again and again that which we see graphed here. These values can be determined either by a long series of successive positions by graphic statics as shown earlier, or they may be more quickly done by the use of the formula developed, applied to a series of assumed angular positions. Care is necessary, however, in the use of these formulas to be sure of the trigonometric signs as shown in Fig. 48. We use the symmetrical position as a

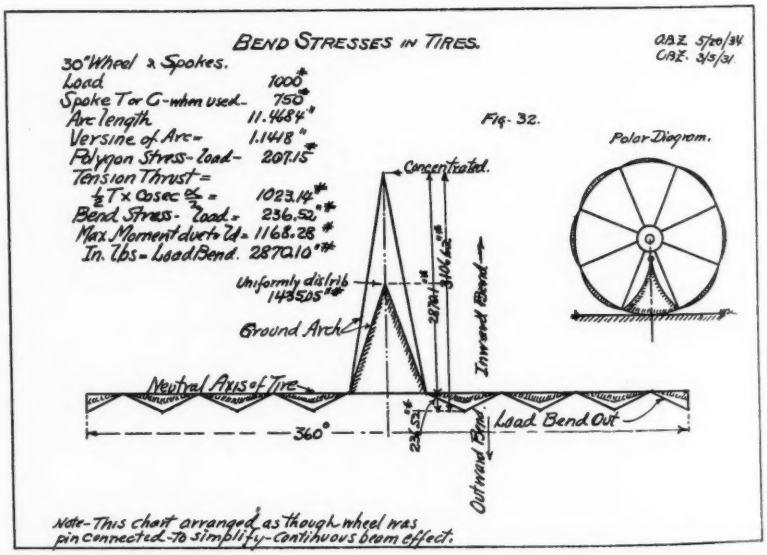


FIG. 32

starting point with ω variations "plus" and "minus" from that position.

Pre-Stressing of Wheels

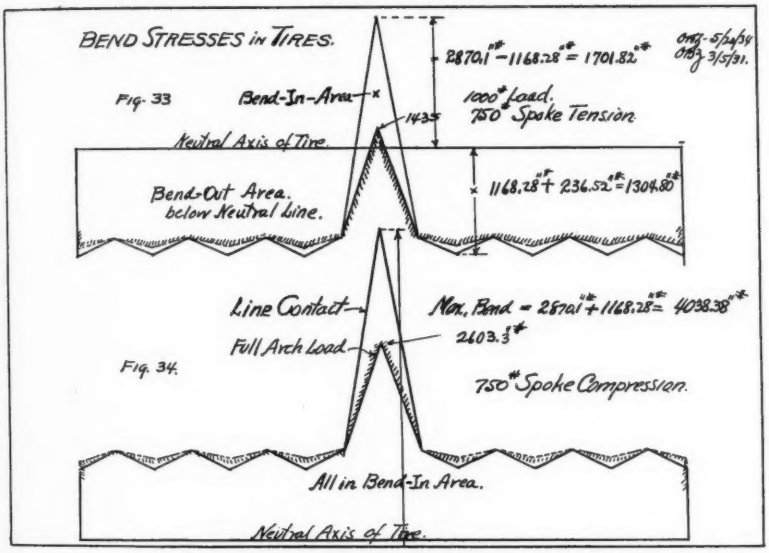
The effect of prestressing using tension next shows that, given the same road conditions of operation, we have—by adding stress in the spokes—changed the amount of stress in the spoke through its cycle of operation, but not the over-all surge pattern. A decrease of load is obtained in the two compression spokes in the passage, thus favoring the column-carrying load possible with a reduction in weight for a given load. If we impress a tension per spoke equal to the load, the neutral line of the diagram drops to the base line (Fig. 25). Thus the nature of the surges is not changed; only the location of the neutral axis.

When we shrink a tire over the spokes and hub structure, we get the third diagram pattern (Fig. 26). This clarifies indisputably the question of enlarged stresses, and unless the practical conditions or material call for this specific set-up, it should not be used. Railway car wheels are a good example of a design requiring shrinkage or compression types. Wagon wheels made largely of wood are another.

To summarize these relationships, the next diagram (Fig. 27) covering the neutral wheel visualizes the relationship which a given load of 1000 lb generates in a series of wheels having different numbers of spokes. The diagram shows values from a three-spoke wheel to one with twenty spokes. We note the curves which depict without heated argument the advantage of one number of spokes over another. The leveling out of both curves from eight spokes on to the right presents a clear argument that an excessive number of spokes is of no advantage. It is a waste. What happens in a disk wheel is indicated by the data of a 180-spoke wheel.

Several diagrams (Figs. 28, 29, and 30) are shown to clarify the graphic statical maximum values. While few low-numbered-spoked wheels are in use, it is desirable to understand them. The composite surges (Fig. 31) for a three, four, five and six-spoke wheel under the same load and operating condition is convincing as to magnitude and number of surges.

As shown before, the neutral line position varies with the tension or compression impressed, but the pattern remains.



FIGS. 33 AND 34

Tires

Having clarified the spoke surges of the radial type and of general coplanar construction, let us investigate the effects on the tire or rim (Figs. 32, 33, and 34).

Again starting with the neutral wheels and setting it up under load, contacting the hard road on a line across the tire, it is clear that the particular arch in contact with the ground receives the greatest stresses. They are bending stresses. This major stress tries to bend the tire inward by an amount due to the load, the strength of the tire section, the nature of the ground, and the number of the spokes or chord length of tire.

From both graphic results and formula deductions, we saw how the compression chord stress pushed between spoke fastenings. The beam effect bridging the gap between two adjacent spokes is thus affected and is clearly compression and bend. This means that, if the chord is under compression, the tire arch is under compression and bend and that the tendency is to buckle out still more than under neutral load strains.

The bending moment of all but the ground arch is outward. The

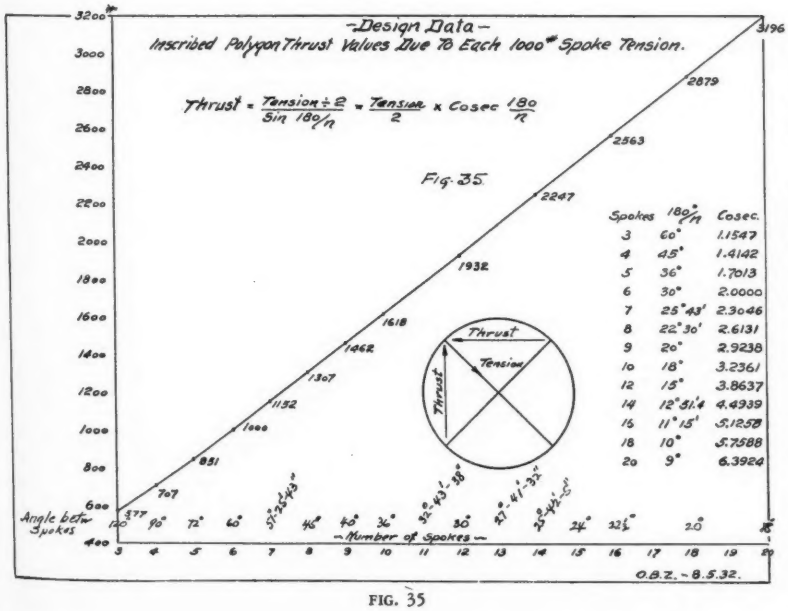


FIG. 35

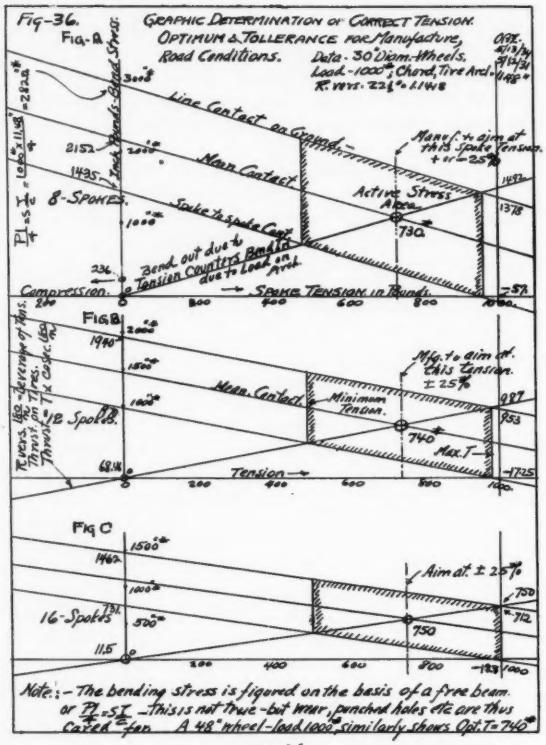


Fig-36.
Graphic Determination of Correct Tension.
Optimum & Tollerance for Manufacture, Road Conditions.
Data - 30" Diam. Wheels. Load - 1000#, Chord, Tire Arc.
Line Contact on Ground
Mean Contact
Active Stress Area
Spoke ½ Spoke Cant
Bend out due to Tension Counters Bend in due to Load on Arch
Compression
Spoke Tension in Pounds
8-Spokes
12 Spokes
16-Spokes
Mean Contact
Minimum Tension
Max. T
Tension
Aim at ± 25%
Note:- The bending stress is figured on the basis of a free beam.

FIG. 36

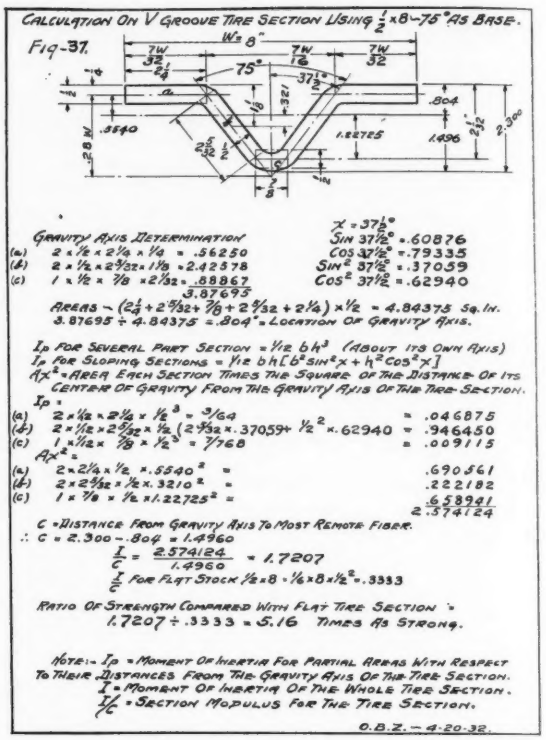

Calculation On V Groove Tire Section Using ½ x 8 - 75° As Base.
Fig-37.
Gravity Axis Determination
Areas
Ip For Several Part Section
Ax² = Area Each Section Times The Square Of The Distance Of Its Center Of Gravity From The Gravity Axis Of The Tire Section.
C = Distance From Gravity Axis To Most Remote Fiber.
Ratio Of Strength Compared With Flat Tire Section
1.7207 ÷ .3333 = 5.16 Times As Strong.
Note:- Ip = Moment Of Inertia For Partial Areas With Respect To Their Distances From The Gravity Axis Of The Tire Section.
I = Moment Of Inertia Of The Whole Tire Section.
I/c = Section Modulus For The Tire Section.
O.B.Z. - 4-20-32.

FIG. 37

magnitude due to this stress along the chord and the offset between the theoretical chord and the section modulus line of the tire cross section, which thus far is considered a flat tire of line thickness but inelastic, must be measured in inch-pounds. The nature of the road surface, if very hard, then makes the application one of a concentrated load, midarch. We thus have the maximum moment. The other extreme condition would be that of a soft road surface which would spread the load from spoke to spoke or more.

As in the spoke stress surge diagrams, we see the effects of neutral, tension, and compression types on the magnitude of the stresses. *Again it is for us to determine what ideal or optimum stress should be used, to meet the engineering requirements for mass production.* While the whole structure helps with the load, the real punishment is in the wheel sector zone, between the hub and the ground, and is as wide as the angle $180/n$, right and left of the vertical radial maximum spoke load line.

When we apply tension in the spokes, we create thrusts between the adjacent joints which are very marked, which thrust, if large enough, can completely counter the inward bend of the load on the ground arch. The formula developed shows that this thrust due to tension is equal to one-half tension impressed times cosec $180/n$. The design data chart (Fig. 35) showing these values per 1000 lb spoke tension is illuminating. It is therefore up to the designer to use his judgment under the conditions he has before him, to balance the load beam stresses, the chord thrust stresses, and the tension impressed.

The desirable allaround proper tension is now up for review.

Determination of the Optimum Spoke Tension

We were definitely impressed earlier in this paper with the influence of prestressing, and now we want to know what is the optimum—*what stress with respect to the average load carried by a given wheel will make the entire structure respond to its assigned activities with the greatest endurance, the minimum economic weight of material, a satisfactory cost, without overemphasis or sacrifice.*

The countering forces acting are the bend-in moments due to load and the bend-out moments due to tension which either balance, compromise, or show excesses. Fig. 36 (A, B, and C) show the application of a relationship for 8, 12, and 16-spoke wheels, all carrying the same uniform load. Since the formulas are straight lines, one countering the other, their intersection is a value common to each; hence, if we assume the tire to ground, midarch, to be a line contact, the intersection for proper spoke tension (Fig. 36A) is around 960 lb optimum. If the wheel operates with a load distributed spoke to spoke on the arch, the lower line sloping down to the right intersects the rising line at 480-lb optimum. For practical purposes it is assumed the mean position for field wheels would answer, or 730-lb tension for the 8-spoke wheel, 740 lb for the 12-spoke wheel, and 750 lb for the 16-spoke wheel.

The active stress area thus permits us to aim at the optimum in manufacture, and have a fair tolerance of 25 per cent plus or minus, which tolerance can be reduced as manufacturing methods improve and show control. Wheels intended to be operated under practically constant hard road conditions should have an optimum tension specified above the mean line, and more nearly the right, say, 850 lb, while wheels normally running in a field well pulverized, as for a grain drill, should be aimed at 650 lb tension. A steel wheel running on concrete or very hard ground or track should be tensed to 950 lb.

It is obvious that the high tensions of chilled hub wheels. where the tire does resist the shrinkage, often

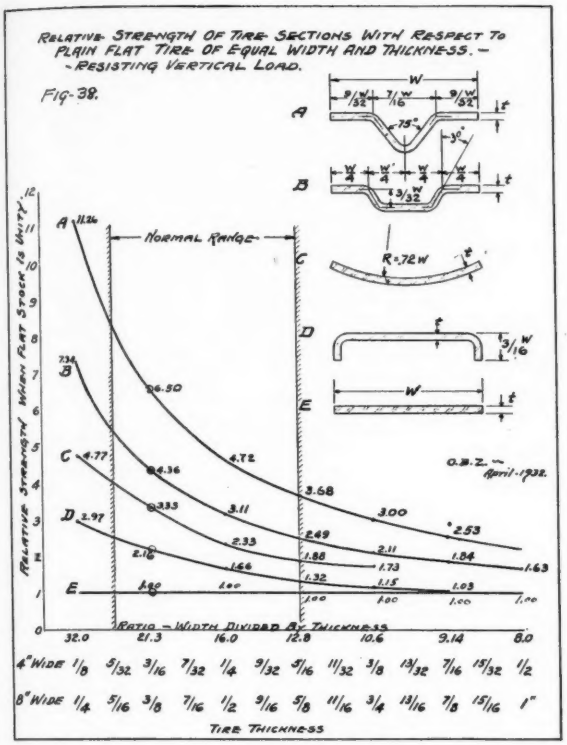

RELATIVE STRENGTH OF TIRE SECTIONS WITH RESPECT TO PLAIN FLAT TIRE OF EQUAL WIDTH AND THICKNESS. — RESISTING VERTICAL LOAD.
FIG. 38.
NORMAL RANGE
RELATIVE STRENGTH WHEN FLAT STOCK IS UNITY
O.S.Z. — April 1932.
RATIO — WIDTH DIVIDED BY THICKNESS
TIRE THICKNESS

FIG. 38

ranges to ten times the load. Such tensions are not desirable, because the entire structure is made empirically subject to the method of manufacture, rather than to the load. Improper riveting-up construction can and does develop equally bad effects. On the other hand, if the tire gives under the strain we have a fluted roundness of the wheel which pulls hard, and the wheel goes dead as to tension.

Tire Sections

Under the heading of "tire sections" we have an opportunity to do some real engineering, both in design and in the shop. Therefore, it is important to know the relative strength of the various tire sections. These strengths can be compared by their section moduli. However, that relation can be more readily visualized by noting the relation existing between a flat tire of equal width and projection and the one investigated. Taking the common sections—flat, flanged, concave, grooved, and V-groove type illustrated in Fig. 38—their relative values can be read off.

Taking the flat tire as a base and equal to 1, for a 4x3/16-in tire the flanged is 2.16 times as resistant to bend; the concave is 3.33; the balanced groove, 4.36, and the V-groove, 6.50, for the proportions calculated. This looks like a worthwhile study.

A typical calculation for the V-groove tire[4], without flanges and of a form modified from that shown in Fig. 38, is given in Fig. 37. Other forms can be treated in like manner according to requirements. The V-groove type with its advantages of strength, of distributing the load to a number of spokes or rigidity in backbone, its adaptability to cross spoking for sidethrust and to lugging, its concentricity, and adaptability to modern high-speed electric-welding manufacture can be noted, along with its strength.

Dynamic Stress Surge Patterns

We must now be convinced that a loaded wheel when in operation is under a great variety of strains which are "dynamic." The wheel is alive in the true sense; there are

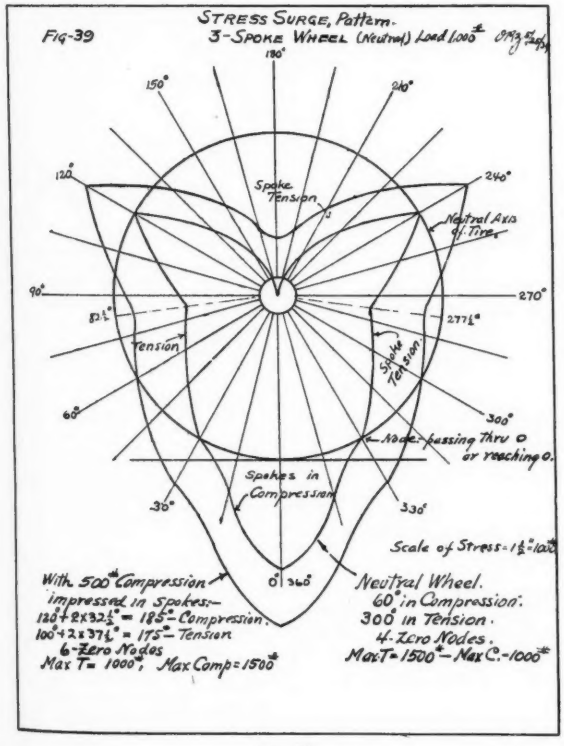

STRESS SURGE, Pattern.
FIG-39
3-SPOKE WHEEL (Neutral) Load 1000#
Spoke Tension
Neutral Axis of Tire
Tension
Spoke Tension
Node passing thru 0 or reaching 0.
Spokes in Compression
Scale of Stress = 1/2" = 100#
With 500# Compression impressed in Spokes:—
120° + 2 x 32 1/2° = 185° — Compression.
100° + 2 x 37 1/2° = 175° — Tension.
6-Zero Nodes
Max T = 1000#; Max Comp = 1500#
Neutral Wheel.
60° in Compression.
300° in Tension.
4-Zero Nodes.
Max T = 1500# — Max C. = 1000#

FIG. 39

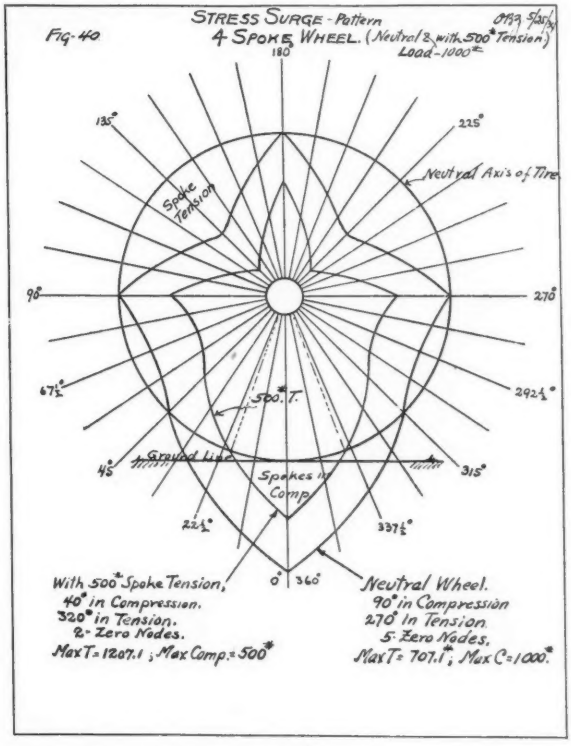


FIG. 40

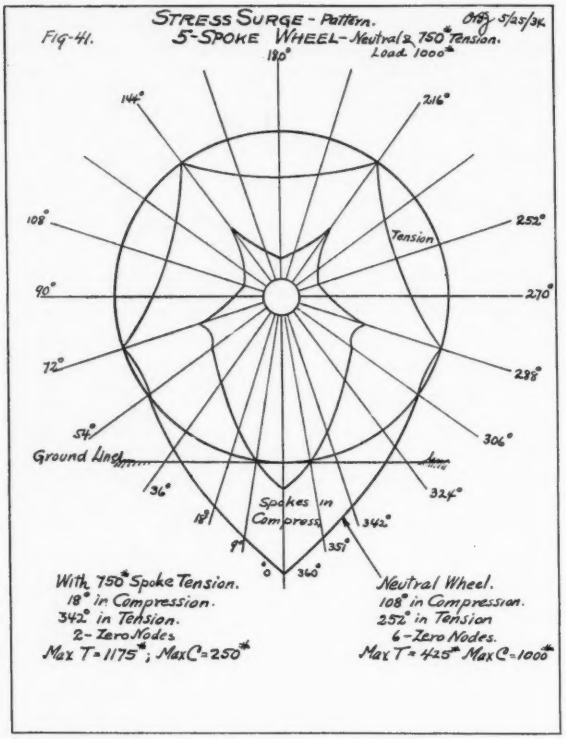


FIG. 41

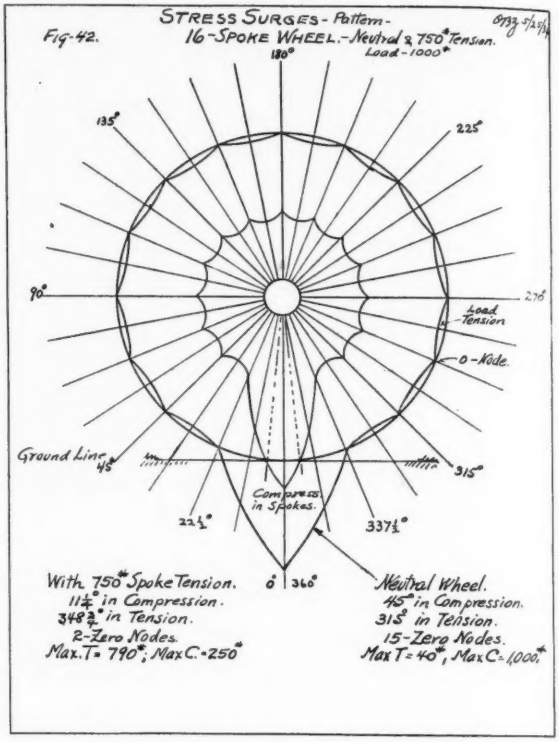


FIG. 42

surges of stress going on in cycles within the wheel elements and through the joints the entire time of its operation. The pushes or pulls, or changes in tension, bend, shear, torsion, or compression, and all their combinations must require special consideration. The structure and its elements must retain their proper relations throughout its active life. Only by a comprehensive understanding of these *dynamic fatigue stresses* can a designer correctly proportion a wheel and use material and method of construction to advantage. If the structure be so fastened together as to permit the joints to work loose, or if the size of parts be such as to cause the elastic limit to be passed, the stability decreases and the value of proper prestressing is lost; noise develops, and breakdowns result. It becomes important that any design or method of manufacture used must lend itself to the principles hereby established.

One more step can be taken now to clarify these surges, and that is by polar diagrams, which are shown in Figs. 39, 40, 41, and 42. The idea here is to envisage not only one spoke at a time, the hub, or one tire sector, but for any instant position of one spoke to tell what the others are doing. In each case we have a neutral pattern which means that, if a plane could travel along back of the wheel, parallel with the ground and centered on the axle, it would carry the stress pattern, and the projected spokes upon the pattern would record by intersections the magnitude and direction of the instantaneous stress; or by revolving a transparent wheel disk with a corresponding number of spokes marked thereon, centered over the pattern, the same readings can be taken or visualized. This will give you a

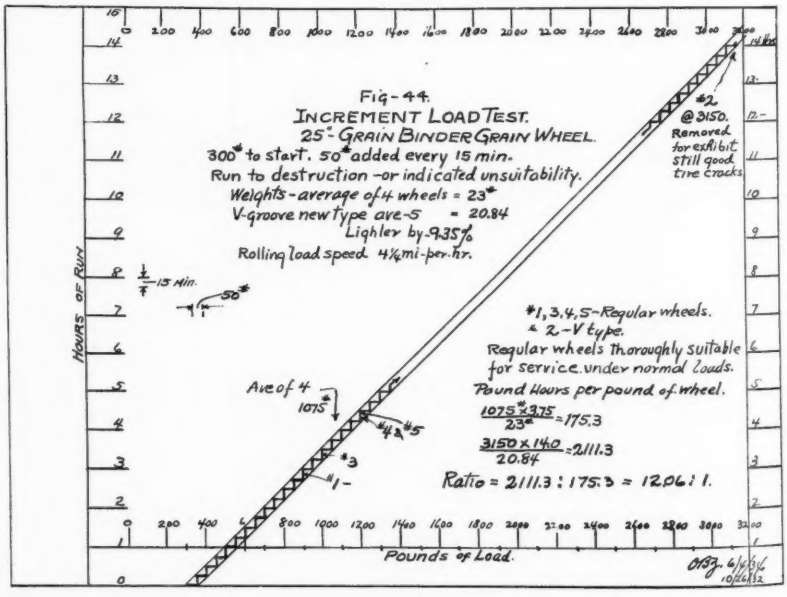


Fig-44.
INCREMENT LOAD TEST.
25"-GRAIN BINDER GRAIN WHEEL.
300# to start. 50# added every 15 min.
Run to destruction -or indicated unsuitability.
Weights - average of 4 wheels = 23#
V-groove new type ave-5 = 20.84
Lighter by 9.35%
Rolling load speed 4¼ mi-per-hr.
#2 @3150. Removed for exhibit. Still good tire cracks.
HOURS OF RUN
½ 15 Min.
50#
#1,3,4,5-Regular wheels.
& 2-V type.
Regular wheels thoroughly suitable for service under normal loads.
Pound Hours per pound of wheel.
1075#×3.75 / 23# = 175.3
3150×140 / 20.84 = 2111.3
Ratio = 2111.3 : 175.3 = 12.06 : 1.
Ave of 4 1075#
#4 & #5
#3
#1-
Pounds of Load.

FIG. 44

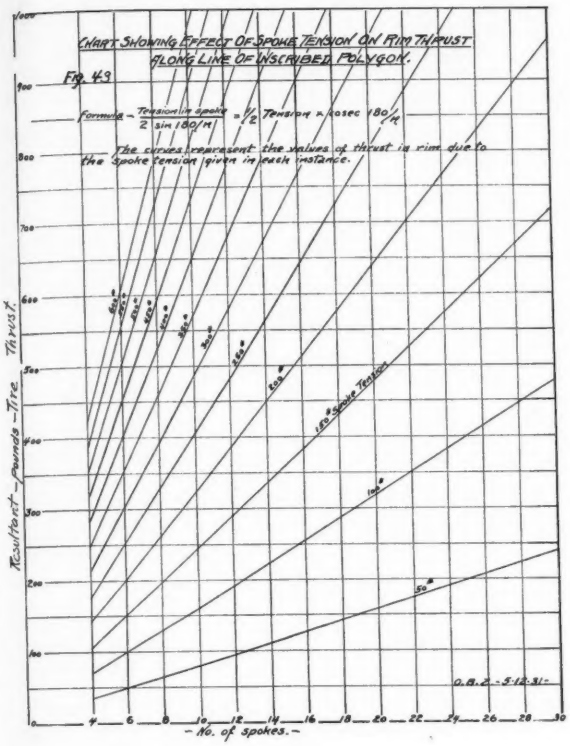


CHART SHOWING EFFECT OF SPOKE TENSION ON RIM THRUST ALONG LINE OF INSCRIBED POLYGON.
Fig. 43
Formula – Tension in spoke / 2 sin 180/n = 1/2 Tension × cosec 180/n
The curves represent the values of thrust in rim due to the spoke tension given in each instance.
Resultant – Pounds – Tire Thrust.
No. of spokes.
O.B.E. - 5-12-31-

FIG. 43

real thrill and plenty of argument for this method. Fig. 39 is diagrammed for neutral and a 500-lb compression stress; Fig. 40 for neutral and optimum tension, 75 per cent of load; Fig. 41 for neutral and 750-lb tension. These four diagrams are full of meat for you to study with respect to wracking effects and fatigue. Fig. 43 is supplemental engineering data on thrust values.

Wheel Test Data

To attempt to give a picture of wheel tests or testing methods at this time is impossible; suffice it to say that static and rolling load tests were necessary. Pilot tests of a considerable variety of wheels of several reliable manufacturers were made to gain a general understanding of the best approach and some idea of how wheels broke down. The upsetting factors were that we were dealing with such variety in structures, in stress, in methods of manufacture and of design, that it was far from the simple problem of a tension test bar. Strain gage tests showed that, even in a single wheel, noticeable variations occurred. It seemed hopeless, but, guided by the above analysis, real progress was finally made. Special fixtures designed to work with standard testing machines or machine tools were devised or used and a special rolling load testing machine was developed with full recording instruments.

The title of this paper and the time allotted preclude the possibility of a comprehensive survey of the outlined program of all major stresses. We have covered radial loads in approximately one plane; we must forego the work on torsion, sidethrust, and pivotal stresses. The approach outlined leads rapidly into these.

It would be undesirable, however, to leave this subject without showing that the foregoing approach in its organization, deductions, and application, is not pure fanciful theory and stunt diagrams, but is real and practical. Two charts of wheel tests must suffice to show what follows the application only in part of these recommendations.

The first is that of a standard 25-in wheel (Fig. 44) whose average weight in current manufacture was 23 lb. The comparable wheel was designed in part to make use of the principles involved. Use was made of the same materials, except for a reduction in weight to 20.84 lb. Under a rolling load test of 4¼ miles per hour, and a starting load of 300 lb, which load was increased by 50 lb every 15 min (the increment load test), each wheel was run until wrecked or until its breakdown was indicated. The record speaks for itself. The new type wheel would have gone some time longer, but was wanted for exhibit. The others were ruined.

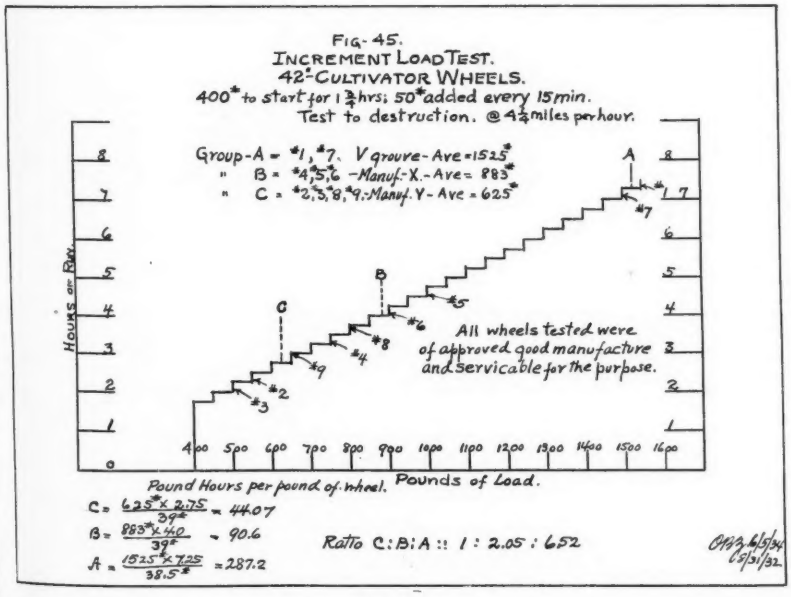


FIG. 45.
INCREMENT LOAD TEST.
42"-CULTIVATOR WHEELS.
400# to start for 1¾ hrs; 50# added every 15 min.
Test to destruction. @ 4¼ miles per hour.
Group-A = #1, #7. V groove-Ave=1525#
" B = #4,5,6 -Manuf.-X.-Ave= 883#
" C = #2,3,8,9.-Manuf. Y-Ave = 625#
Hours on Run.
All wheels tested were of approved good manufacture and servicable for the purpose.
Pound Hours per pound of wheel.
Pounds of Load.
C = 625# × 2.75 / 39# = 44.07
B = 883# × 4.0 / 39# = 90.6
A = 1525# × 7.25 / 38.5# = 287.2
Ratio C:B:A :: 1 : 2.05 : 6.52
Orig. 6/5/34
Corr. 5/31/35

FIG. 45

A similar test was applied to a 42-in series of wheels (Fig. 45) made by three processes for competition—one group standard, one group by another manufacturer, and a third of the V electrically welded type. The weight of the regular wheel was about 40 lb, and of the new wheel 38 lb. The test results again speak for themselves. Many other wheel types showed, by groups, from 4 to 21 times the resistance recorded by well-known commercial types. In six groups of tests, each group covering from two to four manufacturers' products and with several wheels of each make, all considered of good current manufacture and average endurance relations, the mass data showed the average endurance relations to be: Current wheels, 1; new wheels, 12.23. The new wheels did not, at that, have

the advantage of commercial production and control. It is not claimed that all of this gain is the result of material distribution or design, for the greatest gain comes from appreciation of the requirements and then making the process of manufacture conform.

Much discussion could be developed over the proper basis for comparison of wheels. Price per pound is not a true basis, nor is price per wheel. It would appear that a basis of pound-hours of endurance resistance per pound of wheel per dollar expended would be more logical, when the group service was comparable.

It must be very apparent at this point that, while these simple surge data are scaled for perfect conditions of rolling, without modifications of speed, impact, road irregularities over hard or soft contacts, without the operation of the other major stresses—yet it is certain that the wheel, as commonly understood before this analysis, and the wheel now in your vision are quite different, and the possible variations can be conceived. I dare say, therefore, that it is in a far more orderly position in spite of the many intricate points raised by this simple structure.

Summary of Formulas

W = load normally carried

n = number of spokes

D and r = Wheel diameter and radius at neutral axis

α = angle between spokes at hub, in a plane perpendicular to the axle

$\omega = 360/n$, the angle of displacement from symmetrical position

S = stagger or distance between spoke ends in hub parallel to the axle

l = chord length between spoke ends in tire at neutral axis

$= 2\,r \sin \alpha/2 = 2\,r \sin 180/n$

V = versine of $\alpha/2 = (r - r \cos \alpha/2) = r\,(1 - \cos \alpha/2)$

d = hub diameter at spoke entry

T = thrust on tire sectors due to spoke tension

$= \frac{1}{2}$ tension x cosec $180/n = \frac{1}{2}\,t$ cosec $180/n$

t = spoke tension

M = Bending moment on contact arc $= W\,l/4 = SI/c$

M_t = Effect in bending moment due to $T = t\,r$ vers $180/n$

M_w = Load bending on all but lower sector = W secant $\alpha/2$

$R_1 + R_2 = W$

$$AB = \text{lower spoke stress} = W/2\,\frac{\cos \alpha}{\cos \alpha/2} \quad \text{(For symmetrical position)}$$

$$= R_1\,\frac{\cos\,(\alpha - \omega)}{\cos \alpha/2} \quad \text{(For general position)}$$

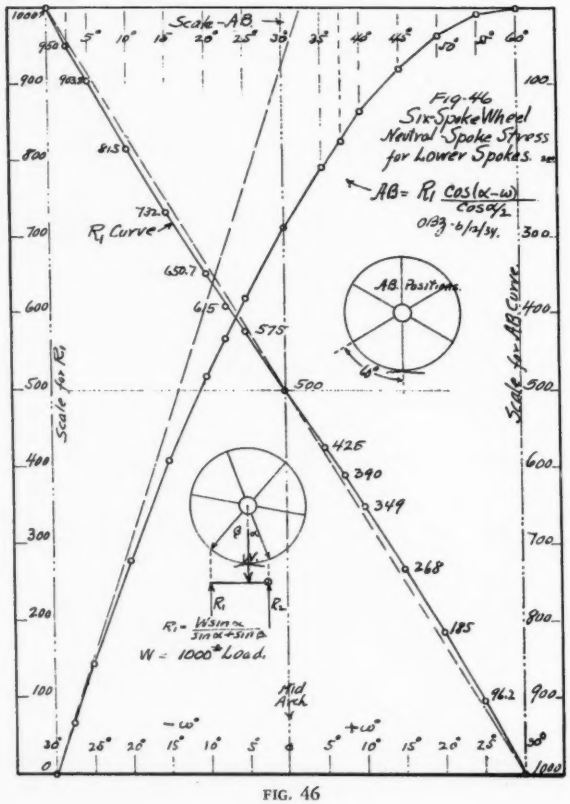


FIG. 46

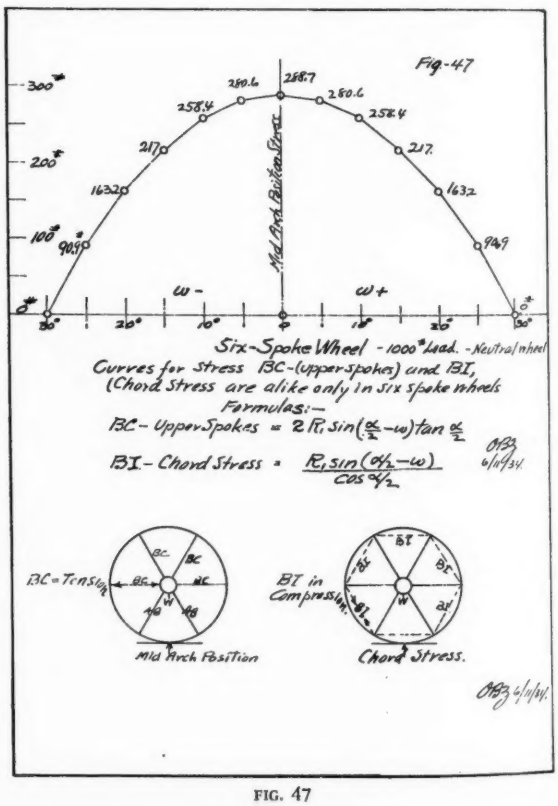


FIG. 47

BC = upper spoke stress = $W \sin \alpha/2 \cdot \tan \alpha/2$ (For symmetrical position)

$= 2 R_1 \sin (\alpha/2 - \omega) \tan \alpha/2$ (For general position)

BI = chord stress = $W/2 \cdot \tan \alpha/2$ (For symmetrical position)

$$= R_1 \frac{\sin (\alpha/2 - \omega)}{\cos \alpha/2}$$ (For general position)

R_1 = unsymmetrical position (or general formula) $= \dfrac{W \sin (\alpha/2 + \omega)}{\sin(\alpha/2+\omega) + \sin(\alpha/2-\omega)}$

(NOTE: This is to be continued for other stresses in a subsequent paper.)

Figures 46, 47, and 48 show the full development and use of the formulas as applied to a six-spoke and to a three-spoke wheel. As the number of spokes increases from three to six, it is noted how the R_1 spoke curve approaches a straight line; the eight and higher number of spokes lie almost exactly on a line.

The only caution in the use of the formulas is to be careful to note the signs and change of signs of ω when dealing with low numbers of spokes, such as a 5, 4, and 3-spoke wheel; also to bear in mind that both symmetrical and general formulas started with midarch contact on the ground. The formulas are of course applicable only to certain zones, and are for the neutral construction, subject to the algebraic + or — due to tension or compression impressed, if such exist.

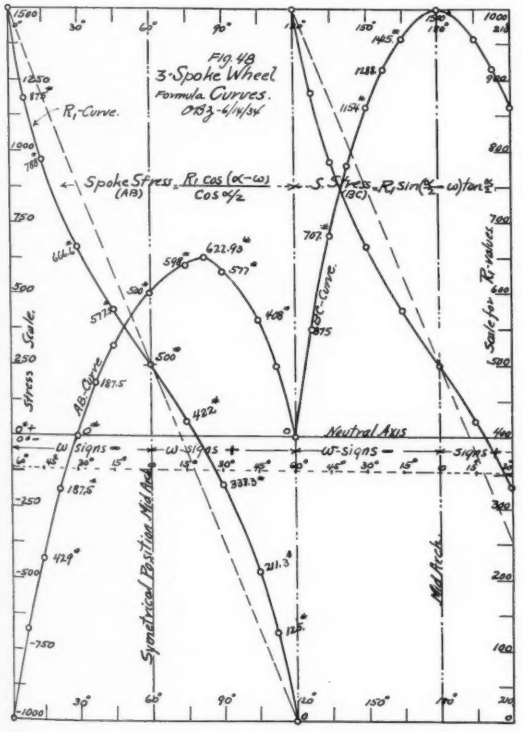


FIG. 48

(NOTE: In Fig. 48, in the formula representing spoke stress through the range of 120 deg to 240 deg, the expression "R_1" should be "2 R_1" instead.)

Why wheels wreck themselves is told clearly by a review of the stress diagrams—Figs. 39, 40, 41, and 42. Where the stress curves meet or go through the neutral stress, the working of the joints at those moments results in wear and wracking. A reduction in the number of nodes is therefore desirable, and is attained by control of tension.

In concluding this discussion, I wish to make the following observations: While the origin of the wheel must remain a mystery, its trails go back deep into the history of Egypt. Rameses II seems to have had good chariots in 1317 B.C., but he was not the first, since the Hittites in their invasion of Egypt about 1800 B.C. introduced them. The ancient city states of the Tigris-Euphrates Valley give us true records of wagons and chariots back of 3500 B.C., from the excavations of Kish and Ur. Crete had them between 3500 and 4000 B.C.—the time of the building of the Pyramids.

Now, with at least 6000 years of empirical development behind us — and that is a long, long time — are we not bound to feel impressed with the difference between those centuries of slow development and the magnificent stride resulting from a few years of technical study? It is believed that this paper is a pioneer presentation dealing with wheel stress surges under load, but in the event it is not, it should call from cover any previous one. Or if there is a better solution, let us have it. Surely this development will centralize and stimulate interest in the oldest known machine element of transport equipment.

While there is evidence in a review of the various ancient wheels that there was a vague appreciation of certain elemental factors of form and available material distribution, it is sure that few if any wheels, ancient or modern, show a positive balanced understanding of the disclosed relationships or principles involved, and reflect that understanding in the product. There are designs in production today whose details are violently incorrect though sponsored by otherwise prominent engineers or firms.

From the foregoing analysis it is safe to say that no amount of cut-and-try wheel experiments could attain equivalent results or unscramble the many purely geometric and design variables and give their relative variations and values. The proper proportioning can only be attained by the technical approach. In all problems where a question arises in the form of a conflict between theory and practice, it is safe to say that some important factor or factors have not been taken into consideration or have not been properly evaluated. Otherwise theory and practice must agree.

This wheel problem is a magnificent example of the thought that science will not compromise with prejudices, ignorance, or notions. She wants facts. Here are some. Use them.

(AUTHOR'S NOTE: The solution of every worthwhile problem in research is the result of constructive cooperation. I wish to acknowledge therefore, with many thanks, the splendid assistance (on the technical side) given me by J. R. Allan, Ralph D. Mancinelli, and Gordon McNamera. Their ability and unfailing loyalty to the problem was necessary to success over this involved, resistant, tortuous path. Professor Florence Allen of the University of Wisconsin checked the formulas in this paper and made constructive recommendations in connection therewith. Those who deserve credit on the commercial side will receive it in due course.)

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture.

CONSTRUCTION AND OPERATION OF MECHANICAL REFRIGERATORS FOR FARMS, *J. R. Tavernetti.* California Sta. Circ. 329 (1933), pp. 35, figs. 17. This circular reports the results of investigations which have been conducted by the station in cooperation with the California Committee on the Relation of Electricity to Agriculture. It presents information of both a practical and technical character on the construction and operation of large mechanical refrigerators for farms.

WELL-PLUGGING PROGRAM SAVES IRRIGATION WATER. Engin. News-Rec. vol. 111 (1933), No. 20, pp. 598, 599. A description is given of a situation in the Boswell artesian basin in New Mexico where old leaky wells have been a constant source of water loss. Studies conducted cooperatively by the state engineer's office and the U. S. Geological Survey showed that many abandoned wells in the basin were permitting the artesian supply to leak into the upper strata. Basic data for well-plugging operations were developed which included the effective use of the deep-well current meter to explore leaky wells in the area. Studies indicated that the losses from the older wells ranged from a fraction of a second-foot to a probable maximum of 5 sec-ft per well.

In general, the plugging procedure finally employed is as follows: A 2-in. diameter pipe is placed into the well at the desired location and fluid mud is pumped into the well until the return fluid indicates a weight of about 12.5 lb per gallon. A final pumping with heavy mud provides a temporary seal and support for cement grout. A neat cement grout is then injected into a pipe followed by sufficient heavy mud to clear the tube of cement. After the seal has been effected the top water is replaced with mud until the well is completely filled with clay. The data to date indicate that the cost of plugging the wells is less than the value of the water saved.

THE PASTEURIZATION OF MILK BY AN ELECTRIC CURRENT, *C. G. King.* Electrochem. Soc. Trans., vol. 62 (1932), pp. 233-236, fig. 1. This is a brief account of the experience of 17 commercial institutions on the electric internal heating of milk for pasteurization. Alternating current is passed through the milk and the entire mass of fluid is easily and evenly heated with a minimum of exposure to either air or metals. Water-cooled carbon plate electrodes are used and the temperature is brought up in two stages —first to 120 deg F and then to 162 deg. It is stated that the pasteurized milk produced has been given repeated satisfactory tests as to efficiency in destroying pathogenic organisms.

VEGETABLE OILS AS INTERNAL-COMBUSTION ENGINE FUEL [trans. title], *A. W. Schmidt.* Tropenpflanzer, vol. 35 (1932), no. 9, pp. 386-389. In a brief contribution from the Technical Academy of Breslau, experiments are reported which showed that vegetables oils are heavy and are suitable for use only in Diesel and semi-Diesel engines. These oils in their natural condition were found unsatisfactory for tractor engines designed for gasoline or benzol fuels. Tests with peanut, soybean, and palm oils in a small Diesel engine showed that the engine ran satisfactorily, although some difficulty was sometimes experienced with starting. This was overcome by starting on such a mineral fuel as benzol. The power output of the engine was considerably less with vegetable oils than with mineral fuels, this being in the ration of 15:24. This was found to be due partly to the lower calorific value of the oil and also to the improper atomization and imperfect combustion resulting from higher viscosity.

CZECHOSLOVAKIAN ALCOHOL-BENZOL MIXTURES [trans. title], *A. Balada.* Chem. Obzor, vol. 7 (1932), no. 11, pp. 240-244, fig. 1. Studies are reported which showed that when benzol is mixed with alcohol there is an increase in the mixture volume accompanied by a decrease in temperature. The characteristic qualities of the benzol are changed considerably by the addition of alcohol to benzol, which fact must be considered in evaluating the mixture as a motor fuel. This is especially important with reference to the starting capacity of mixtures at the 10 per cent point. Heavy benzols, the 10 per cent point of which decreased after adding alcohol even below the 10 per cent point of the representative light benzol from the same raw material, did not start better than the latter. Data are also included on values of octane numbers of Czechoslovakian benzol and benzol mixtures.

UTILIZATION AND COST OF POWER ON CORN BELT FARMS, *L. A. Reynoldson, W. R. Humphries, S. R. Speelman, E. W. McComas,* and *W. H. Youngman.* U. S. Dept. Agr., Tech. Bul. 384 (1933), pp. 60, figs. 12. The information forming the basis of this bulletin was obtained in the fall and winter of 1929-30. It represents a cooperative investigation between the Bureau of Agricultural Economics, Agricultural Engineering, and Animal Industry.

Data are presented on the use and cost of power on 736 farms in 11 areas in Michigan, Indiana, Illinois, Iowa, and Missouri. The total number comprised 280 ordinary tractor farms on which a conventional noncultivating type of two or three-plow tractor was owned, 79 general-purpose tractor farms, 343 ordinary horse farms, and 34 big-team-hitch farms. The big-team-hitch farms averaged 286 acres, and the ordinary horse farms averaged 179 acres with 252 and 137 acres of crop land, respectively.

Average annual usage, including small amounts of hired power, on the ordinary tractor farms was 315 tractor-hours and 3,885 horse-hours per farm; on the general-purpose-tractor farms, 488 tractor-hours and 2,856 horse-hours per farm; on the ordinary horse farms, 17 tractor-hours and 4,163 horse-hours per farm, and on the big-team-hitch farms, 34 tractor-hours and 8,219 horse-hours per farm.

Tractor usage on the home farm averaged per year 471 h for the general-purpose tractors, 301 h for the two-plow tractors, and 297 h for the three-plow tractors. Seventy-three per cent of the general-purpose tractors were used in cultivating row crops. Fifty-eight per cent of all the tractors performed custom work, of which two-thirds in time was belt work.

Work-stock usage on the home farm averaged 736 h per head on the big-team-hitch farms, 688 h on the ordinary horse farms, 681 h on the three-plow-tractor farms, 643 h on the two-plow-tractor farms, and 641 h on the general-purpose-tractor farms per year.

The average period of use of the tractors, up to the time of the survey, was 4.3 years for the three-plow tractors, 3.8 years for the two-plow tractors, and 2.0 years for the general-purpose tractors. The total useful life of the tractors was estimated most commonly by the users as 10 years.

The total costs per hour of operation in 1929, omitting wages of the operator, were $1.13 for the three-plow, 80 cents for the two-plow, and 61 cents for the general-purpose tractors. The fixed charges of depreciation and interest on investment were 51 per cent for the two and three-plow tractors and 45 per cent for the general-purpose tractors. At prices of fuel, oil, and labor prevailing during the year ended June 30, 1932, the hourly costs, omitting operator's wages, would have been lower by about 10 per cent for the three-plow tractors, 12 per cent for the two-plow tractors, and 14 per cent for the general-purpose tractors.

For all classes of farms the average cost per crop acre, exclusive of operator labor, was lowest in 1929 on the general-purpose-tractor farms at $2.91, and at 1931-32 prices appeared lowest on the big-team-hitch farms at $1.74.

Corn grown in the ordinary way showed a lower cost per acre for labor and power when husked with a two-row picker than when harvested by any other method observed. Oats showed the lowest cost per acre for labor and power in growing and harvesting when seeded with an end-gate seeder. The requirements and costs for wheat were but slightly different from those for oats handled in the same way. Hay cost less for labor and power when loaded with a loader from the windrow than when loaded from the swath or by hand from the windrow.

A SOIL STERILIZER, *W. C. Krueger.* N. J. Agr., vol. 15 (1933), no. 4, pp. 7, 8. A very brief account is given of experiments on the sterilization of soil by electricity.

SEWAGE DISPOSAL, *W. Rudolfs.* N. J. Agr., vol. 15 (1933), no. 3, pp. 7, 8. Very general and brief information is given on the use of sewage gas as a source of power for heating and pumping. Experiments with a plant treating the sewage from a population of 7,000 people was found to produce an average of 5,600 ft of gasoline per day.

IRRIGATION REQUIREMENTS OF THE ARID AND SEMIARID LANDS OF THE PACIFIC SLOPE BASINS, *S. Fortier* and *A. A. Young*. U. S. Dept. Agr., Tech. Bul. 379 (1933), pp. 70, figs. 6 This is the fifth and final report of a series dealing with the irrigation requirements of crops in the arid and semiarid lands of the Western States. Much of the investigational work on field crops summarized in this bulletin was conducted in cooperation with the Department of Public Works of the state of California, and with the California Experiment Station.

The statistical data on irrigation of semitropical fruits and nuts in southern California were obtained mainly from studies conducted by the agricultural extension service of the University of California in cooperation with the U. S. Department of Agriculture. A large amount of data is presented and analyzed, and 32 references to literature bearing on the subject are included. An appendix gives data on irrigation water applied, rainfall, and crop yields in Oregon and California.

HEAT TRANSMISSION, *W. H. McAdams*. McGraw-Hill Book Co., New York and London, 1933, pp. IX+383, figs. 127). This is a handbook for practicing engineers containing chapters on conduction, heating and cooling of solids, radiation of heat, dimensional analysis, flow of fluids, introduction to convection, fluids inside pipes, fluids outside pipes, condensing vapors, and heat transfer to boiling liquids.

SPRAY MACHINES AND EQUIPMENT, *F. Godbout*, Quebec Dept. Agr. Bul. 124 (1933), pp. 1-7, figs. 7. Descriptions and illustrations are given of power sprayers and their accessories.

A COMPARISON OF VARIOUS HARVESTING METHODS IN RESPECT TO MOISTURE AND GRADE OF THE GRAIN, *R. K. Larmour, W. F. Geddes*, and *D. Cameron*. Canad. Jour. Res., vol. 9 (1933), no. 5, pp. 486-501, fig. 1. The work on which this report is based was conducted cooperatively by the Universities of Manitoba, Saskatchewan, and Alberta.

In a moisture and grade survey of grain harvested by various methods in western Canada during the 1932-33 season, it was found that straight-combined wheat showed a greater percentage of tough and damp samples than either stook-threshed or swath-combined samples. With respect to grade it was found that as a result of exposure to rains the average grade lowering was least for stooked grain and greatest for swath-combined grain.

COOLING AND AIR CONDITIONING FOR COMFORT, *W. Goodman*, Aerologist Pub. Co., Chicago, 1932, pp. 93, figs. 8. This pamphlet relates to the theory and calculations of the subject and comprises an intricate mathematical analysis. An appendix includes tabular and graphic data.

IMPROVEMENTS IN THE SOIL COMPACTOMETER AND NOTES ON ITS PERFORMANCE, *C. Davies*. Jour. Southeast. Agr. Col., Wye, Kent, no. 28 (1931), pp. 237-242, figs. 5. In a contribution from the department of engineering of the South-Eastern Agricultural College of the University of London, a description is given of improvements in an instrument used for measuring the degree of the consolidation of the soil under the influence of tillage and traction machinery. Tests with this apparatus led to the conclusion that the shapes of all cutting edges and piercing points can be designed in a way conducive to the least expenditure of energy for the work to be done. Further work is to be conducted with plowshares, colters, tines, digging forks, mole plows, and similar soil-working tools.

PHYSICAL AND CHEMICAL EXAMINATION OF PAINTS, VARNISHES LACQUERS AND COLORS, *H. A. Gardner*. Inst. Paint and Varnish Res., Washington, D. C., 1933, 6th ed., pp. 1174+A350+16, pl. 1, figs. 393. This is the sixth edition of this handbook. It contains chapters on hiding power and brightness; tinting strength of white pigments; tone and strength of colored pigments; ultraviolet studies on pigments and liquids; color systems; color standards for liquids and resins; preparation of films; drying time; hardness, abrasion, and adhesion; gloss measurements; exposure tests; accelerated weathering tests; temperature and humidity control; miscellaneous tests; oil absorption of pigments; consistency determinations; surface and interfacial tension; specific gravity determinations; particle size; examination of oils, driers, thinners, resins, shellac, paint, and varnishes; bituminous paints and baking enamels; examination of waxes; raw materials for cellulosic coatings; physical tests on cellulosic coatings; analysis of cellulosic coatings; and specifications.

SOIL HEATING—A LOAD BUILDER, *G. A. Reitz*. Elect. World, vol. 102 (1933), no. 24, pp. 762-764, figs. 4. A brief description is given of several different experiments on the use of electricity for the heating of greenhouse and hotbed soils.

ALCOHOL AS A POSSIBLE SOURCE OF MOTOR FUEL, *A. L. Teodoro*. Sugar News, vol. 14 (1933), no. 2, pp. 81-83. In a brief contribution from the department of agricultural engineering of the University of the Philippines, results of tests of the use of alcohol as motor fuel are briefly summarized.

It was found that the operation of gasoline engines on alcohol was smooth and silent and devoid of fuel knock. Alcohol could be used with very high compressions, and at high compressions the fuel consumption decreased and the power output increased. Crankcase oil dilution was less with alcohol fuels than with hydrocarbon fuels. On the other hand, at the same compression ratio the consumption of alcohol was greater per unit of power output than with hydrocarbon fuels and starting was difficult at a compression ratio best suited for gasoline. Data are also presented on the use of alcohol in engines designed for kerosene. The results were not so favorable as those secured with gasoline engines.

SEPARATE ROUGHNESS COEFFICIENTS FOR CHANNEL BOTTOM AND SIDES, *R. E. Horton*, Engin., News-Rec., vol. 111 (1933), no. 22, pp. 652, 653, figs. 3. Data and a mathematical analysis are presented, indicating that when the bottom and the sides of an open channel are of different degrees of roughness the equivalent coefficient for the channels as a whole varies with the depth of flow. Formulas are presented which are considered to be a marked improvement over existing methods of determining values of n applicable to channels with two degrees of roughness.

A COMPARISON OF CUP-FEED AND FORCE-FEED CEREAL DRILLS, *C. Davies*. Jour. Southeast. Agr. Col., Wye, Kent, no. 28 (1931), pp. 243-266, pls. 4, figs. 2. Tests conducted by the department of engineering at the South-Eastern Agricultural College of the University of London are reported which included five drills, two of the cup-feed and three of the force-feed type.

Tests in the laboratory to determine the intercolter differences disclosed the fact that the cup-feed drills, which were fitted with adjustable shutters and mechanism for altering the angles of the hoppers, were incapable of giving good intercolter performances unless the shutter apertures and angles were those found by elaborate trial best suited to the drill. On hilly fields the angles would alter frequently. The force-feed machines had no shutters, and they were not much affected by altering the angles of the hoppers.

The effects of speeds of 1, 2, 3, 4, and 5 mph (miles per hour) on the drills were determined. It was found that at the higher speeds the intercolter differences of the cup-feed drills were considerably increased, and the deliveries, in bushels per acre, also varied. In one drill it rose to nearly 14 bu per acre at 5 mph when set to sow at 5 bu per acre. Neither the intercolter differences nor the per acre rates were sensibly altered by speed fluctuations where the force-feed machines were concerned.

Another angle test was employed. This time one end of the hopper of each drill was raised, giving it a 1 in 10 incline. This seriously upset the intercolter performance of one of the cup-feed machines. The tilting had no appreciable effect on the force-feed drills.

The performances along the colter rows were studied in the laboratory and in the field, specially devised methods, which are described, being used. The method used in the field gave an idea of the per-inch as well as the per-foot distributions. The force-feed drills gave better distributions along the rows than the cup-feed. It was concluded that two of the force-feed drills were likely to be better machines for grain growers than the others.

The weight of grain in the hoppers had no influence upon the mean colter deliveries in any of the drills. The method of determining the speed fluctuations in the field is described. These varid from 1.7 to 5.25 mph. None of the drills caused any measurable damage to the grain.

THE EXPERIMENTAL WORK OF THE DEPARTMENT OF ENGINEERING, *C. Davies*. Jour. Southeast. Agr. Col., Wye, Kent, no. 28 (1931), pp. 284-287. In a contribution from the department of engineering of the South-Eastern Agricultural College of the University of London, a description is given of the experimental program, including soil cultivation experiments and experiments on drilling, ridging wheat, transplanting of cabbage plants, and manure distribution.

A METHOD OF TESTING LOW-PRESSURE CHARACTERISTICS OF OILS AND GREASES, *E. F. Bittner*. Natl. Petrol. News, vol. 24 (1932), no. 42, pp. 31-33, fig. 1. A test is described which has proved of value in predicting cold weather behavior of steering gear, transmission, and differential lubricants. In this test a steel ball is suspended in the lubricant by means of a wire, the entire assembly is chilled to the desired temperature, and the ball is then pulled out by means of a spring balance *(Continued on page 310)*

AGRICULTURAL ENGINEERING

ESTABLISHED 1920

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Contributions of interest and value, especially on new developments in the field of agricultural engineering, are invited for publication in this journal. Its columns are open for discussions on all phases of agricultural engineering. Communications on subjects of timely interest to agricultural engineers or comments on the contents of this journal or the activities of the Society, are also welcome.

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RAYMOND OLNEY, *Editor*

R. A. PALMER, *Associate Editor*

Integration of Fundamental Engineering Research

THE 28th ANNUAL MEETING of the American Society of Agricultural Engineers at Detroit was the scene of what may well may be—and surely should be—the beginning of a mighty integration in engineering. In the city which symbolizes the wheel as used in modern highway transport was presented its first truly technical analysis. It was treated from the agricultural equipment angle by an outstanding agricultural engineer, Col. O. B. Zimmerman, and represented five years of research under the sponsorship of the largest unit in the farm machinery industry.

So, too, Detroit saw Prof. M. L. Nichols receive the Cyrus Hall McCormick gold medal in recognition of ten years of research into the elusive laws of soil dynamics, and the evolution of the first reasonably simple mathematical description of the plow. Wheel and plow, the fundamental implements respectively of transport and tillage, both seem to be older than any recorded history, yet their technical analysis awaited one of the youngest of the organized professions, agricultural engineering.

The soil and the plow may be taken for granted as distinctly within our own special field. The wheel, however, runs through all branches of engineering so universally that Col. Zimmerman's contribution is a substantial repayment of the borrowings which agricultural engineering, as a young technology, has made from the older branches. What he has done for the wheel (including material yet to be published) remains to be done for practically all of the machine elements. In making his work possible his company set an example to other industrial units. Indeed, we think it creates a moral obligation on all such, each in proportion to its size and facilities.

In pressing back the technical horizons common to all units in an industry, or to several industries, there is no place for competitive secrecy or of narrow exclusiveness. Detroit offers an example of an industry which retains all the advantages of vigorous competition while the whole industry gains by pooling its technical advancement. That public agencies, such as those represented by Prof. Nichols, are applying themselves to basic research which serves the agricultural industries—and would serve them more if they recognized it more fully and applied it more promptly—is no excuse for neglect of fundamental research by commercial units.

There are problems aplenty to occupy the attention of both avenues of research. More important, those problems assort themselves logically on the basis of facilities available, both of physical equipment and the type of personnel. Once the moral responsibility for research is conceded, it becomes mainly a question of efficient allocation and correlation of work. On the publicly supported side, the Office of Experiment Stations in the U. S. Department of Agriculture does valuable correlation.

To assist in the apportionment of research problems among industrial units, and their correlation with publicly-supported research, the professional technical society seems the ideal agency. Organized on a purely personal basis, without formal or financial connection either with public agencies or private industry, it commands the respect and recognition of each. In its field the American Society of Agricultural Engineers already has encouraged and advised research to a worth-while degree. It is ready, qualified, and anxious to do much more.

That Prof. Nichols has served many industrial units, as well as agriculture at large, is obvious and logical. Though successively in the service of educational institutions, the army, three major farm equipment companies, and other commercial units, all of which he served with distinction, no one of them, nor all of them combined, have reaped or can reap the full value of Col. Zimmerman's research and developmental work. His work on the National Screw Thread Commission, federal and state corn borer control agencies the Committee on the Relation of Electricity to Agriculture, not to mention active membership in at least ten technical societies in the course of a long career, have served industry and agriculture at large. His contributions cannot be converted into allocated costs. The only possible thing, the equitable and creative thing, is for other companies and other men to make similar contributions to the common cause of engineering research.

Our Brother's Keeper: Soil Protection

EVERY AGRICULTURAL ENGINEER—not alone those directly concerned with land reclamation—should study Mr. B. P. Fleming's paper appearing elsewhere in these pages. In it he gives convincing answer to those skyscraper sophists who argue the inconsistency (to them) of protecting our soil resources at the same time that we attempt to limit crop production. He shows the sublime inconsistency of inviting eternal famine to balance an ephemeral surplus.

Though they know it not, the soil erosion problem is of more concern to the urban masses than to rural folk actually on the land. The soil problem, the silt problem, and the flood problem are but aspects of the same general condition. In time of flood it is in the cities that heavy loss of life and destruction of property occur. When a dam breaks a few farms will be damaged, but a whole town may be swept away. The silt stolen from the farmer's soil fills the city's water reservoir and wipes out the investment in its storage capacity.

Basicly, large and prosperous cities depend on the soil.

The family on the land usually survives somehow, even though reduced to a subsistence level, but the very existence of the city depends on surplus food supply, while its prosperity hinges on cheapness of food and on purchasing power of the food producer as a market. That means efficient soil.

Within our own ranks, soil erosion threatens every branch of the profession. Gullied fields are no place to operate combines or pick-up hay-balers, even if yields were sufficient to make them economic. As the soil disappears, so does the need for crop storages and animal shelters. Waterpower may generate electricity, but waterpower denuding a farm of soil denudes it also of purchasing power for electricity. Agricultural engineers in education will be "washed out" even as are the farms they serve.

Though it uses machinery, power, explosives, concrete, and other structural materials, we are likely to dismiss land reclamation as lacking commercial motivation. In a short-sighted way this is true, but in reality soil protection supports the whole agricultural market and much of the urban market as well. Because we cannot expect the lay public to grasp this fact, it becomes doubly our duty to understand it and interpret it—to become protagonists for our brethren in modern land reclamation.

NEWS

A.S.A.E. Meetings

MEMBERS and others will be interested in the schedule of technical meetings of the American Society of Agricultural Engineers to be held during the next twelve months.

The first meeting that has been scheduled is that of the North Atlantic Section of the Society to be held at Massachusetts State College, Amherst, October 17, 18, and 19. C. I. Gunness, head of the agricultural engineering department of that institution, is chairman of the program committee and will welcome suggestions from interested A.S.A.E. members on subjects and speakers for the program.

Taking these meetings in their chronological order, the next on the schedule of ASAE meetings are those of the technical divisions to be held at Chicago the first week in December, during the International Livestock Exposition. The Structures Division will meet at The Stevens, December 3 and 4, for a two-day session. Suggestions for the program will be welcomed by the chairman, W. G. Ward, Kansas State College, Manhattan.

While not yet definitely decided, it is anticipated that the Land Reclamation Division will meet at the same place, December 5 and 6. The chairman of this division. L. A. Jones, Bureau of Agricultural Engineering, U. S. Department of Agriculture, Washington, will welcome comments from members on whether or not they believe a meeting of the Division should be held at that time, and, if so, their suggestions for program topics and speakers will be welcomed.

The Power and Machinery Division of the Society will meet as usual during the same week, December 3 and 4, and while the program for the two-days' session has been quite definitely settled upon, the chairman of the Division, A. W. Lavers, chief engineer, tractor division, Minneapolis-Moline Power Implement Company, will welcome suggestions from members.

This meeting of the Power and Machinery Division will be in the nature of a cooperative meeting with the tractor and industrial equipment group of the Society of Automotive Engineers. Those in charge of arranging the program for both groups are collaborating in the preparation of a program that will be of special interest to engineers in the tractor and farm machinery industry. The SAE program will be presented at the same place, on December 5 and 6.

Next in the schedule of ASAE meetings is that of the Pacific Coast Section of the Society, which will be held at the Oregon Agricultural College, Corvallis, December 28 and 29, the program of which is being planned to feature subjects of particular agricultural engineering interest to members of the Society and other interested persons in the Pacific Northwest. Suggestions for subjects to be presented on this program will be welcomed and should be referred to the secretary of the Section, Walter W. Weir, 320 Hilgard Hall, Berkeley, Calif.

Early in the new year the Southern Section of the Society will meet as usual with the Association of Southern Agricultural Workers, whose next meeting will be held at Atlanta, Georgia. This meeting is usually held the latter part of January or early in February. Suggestions for the agricultural engineering program will be welcomed by the secretary of the Section, J. B. Wilson, Alabama Polytechnic Institute, Auburn

The next important event in the line of ASAE meetings—and the high spot of the ASAE year—is the 29th annual meeting which will be held either the second or third week in June at the University of Georgia, Athens. Suggestions for the program of this meeting should be sent to the chairman of the Meetings Committee. Charles E. Seitz, Virginia Polytechnic Institute, Blacksburg, and suggestions on inspection trips and other matters pertaining to local arrangements should be addressed to the chairman of the committee on arrangements, R. H. Driftmier, Athens Georgia.

Personals

Hobart Beresford and *Elmer N. Humphrey,* agricultural engineers, University of Idaho, are joint authors of Bulletin No. 202, entitled "Prolonging Plowshare Service," recently issued by that institution.

Hobart Beresford, professor of agricultural engineering, University of Idaho, is one of the authors of Bulletin No. 203, entitled "The Bin Method of Mixing Feed," recently issued by that institution.

Geo. W. Kable has been appointed senior designing engineer, agricultural-industrial division, Tennessee Valley Authority, Knoxville, Tenn. He was formerly director of the National Rural Electric Project at College Park, Md.

W. C. Krueger, extension agricultural engineer, New Jersey State College of Agriculture, is author of extension bulletin 126, entitled "Belt and Pulleys," just issued by that institution.

Howard Matson was recently appointed agricultural engineer in charge of engineering work on project No. 20 of the Soil Erosion Service, U. S. Department of the Interior, located at Lindale, Texas. He was formerly on the staff of the agricultural engineering department at the University of Kentucky.

New ASAE Members

Halstead N. Colby, extension assistant and instructor in agricultural engineering, University of New Hampshire, Durham, N. H.

W. C. Gillham, research assistant in agricultural engineering, University of Illinois, Urbana, Ill. (Mail) 704 W. Stoughton St.

Paul W. Jenicek, engineer-foreman, Illinois Department of Conservation. (Mail) ECW Camp 55-PE, Jerseyville, Ill.

James V. MacNutt, ventilation salesman, James Manufacturing Company. (Mail) 48 Colonial Road, Portland, Me.

Aldert Molenaar, assistant extension agricultural engineer, College of Agriculture, University of Nebraska, Lincoln, Nebr.

Leonard E. Nelson, agricultural engineer, 4156 28th Ave. S., Minneapolis, Minn.

David E. Nims, sales and development engineer, Chrysler Motors, Amplex Division, Detroit, Mich.

Bernard H. Osterloh, agricultural engineer, Forest Service, U. S. Department of Agriculture, Nebraska City, Nebr.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the July issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Ralph Hay, assistant in research and teaching, department of agricultural engineering, University of Illinois, Urbana, Ill. (Transfer of grade)

Joseph A. Payette, field engineer, U. S. Tire Company, Inc., 6600 E. Jefferson Ave., Detroit, Mich.

Claude H. Van Vlack, associate professor of agricultural engineering, Iowa State College, Ames, Iowa.

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I have sold about six sets in the last two months with sure prospects of selling 50% of the steel wheel tractors on pneumatics. This fall I am looking forward to nice profits to be made in the Tractor Tire department of my business, as I have already reaped a good profit from them.

During the present dry season it is especially noticeable that the Firestone Tractor Tires do not throw dirt and dust, as do the steel wheels and competitive tires, one of the many features that give Firestones the great preference over the competitors. I estimate that 85% of all Tractor Tires in use throughout this whole section are Firestones. As a result of our success in this field, we are soon putting in your complete line of tires and all Firestone products.

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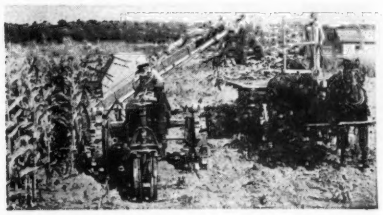

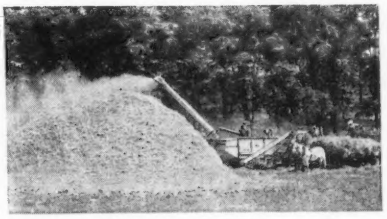

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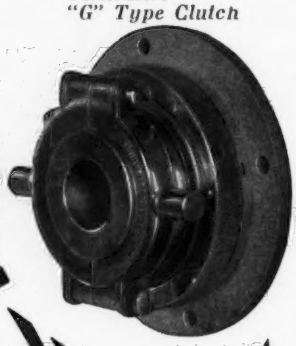

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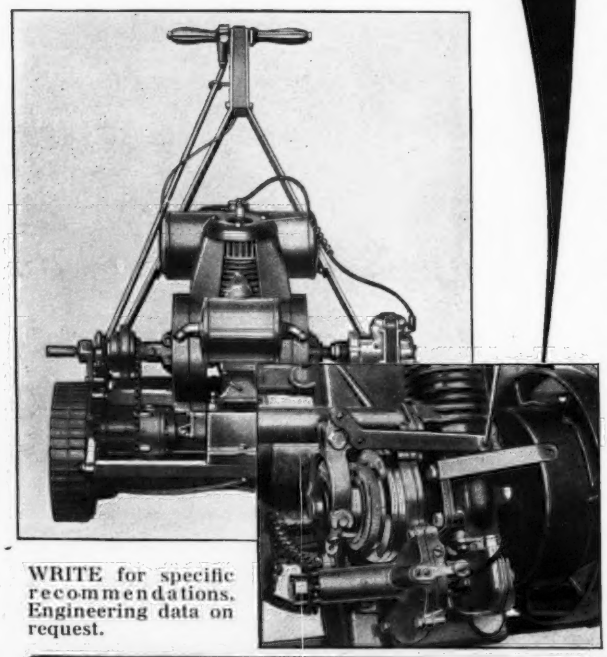

WRITE for specific recommendations. Engineering data on request.

TWIN DISC CLUTCHES

Agricultural Engineering Digest

(Continued from page 303)

or other suitable means of determining the resistance to flow. Practical tests have confirmed the predictions made from the laboratory results.

MOLE DRAINING, *C. Davis*. Jour. Southeast. Agr. Col., Wye, Kent, no. 28 (1931), pp. 296-299. In a contribution from the department of engineering of the South-Eastern Agricultural College of the University of London, information is presented on accepted practice on mole draining in England.

LOW MANIFOLD TEMPERATURES MINIMIZE TROUBLE WITH GUM, LABORATORY EXPERIMENTS SHOW, *S. P. Marley, W. P. Ridenour,* and *W. A. Gruse*. Natl. Petrol. News, vol. 24 (1932), no. 44, pp. 22-28, figs. 4. In a contribution from the University of Pittsburgh, data are presented from preliminary experiments on the significance of gum content of gasoline as related to gum deposits. The results were obtained under laboratory conditions with experimental equipment.

The work included a study of deposits in both intake manifold and combustion chamber and of deposits with the same fuel in full-size, single-cylinder engines. In both cases the manifold temperatures were varied over a considerable range. The conclusion is drawn that a moderate gum content can be tolerated in an engine if the temperature of the mixture in the manifold is kept low. As soon as much heat is applied a fuel containing an appreciable amount of gum will begin to deposit this gum, and such deposits are heavier from a rich mixture than a lean one.

The carbon deposits in the combustion chamber are somewhat but not much greater with gum-bearing fuels at low intake temperatures, but the well-known tendency to lower carbon deposits with higher heat temperatures could readily be invoked to remedy this difficulty. The results as a whole suggest that by lowering intake manifold temperatures volatile gasolines of moderate gum content may perhaps be used without serious trouble from gum deposits.

EXTREME PRESSURE LUBRICANTS, *O. L. Maag*. Natl. Petrol. News, vol. 24 (1932), no. 46, pp. 53, 54, 56, 59, 61, figs. 8. Laboratory data are given on load-carrying capacity, corrosiveness, stability, and a brasive properties of various types of gear and bearing lubricants.

ELECTRICALLY HEATED DAIRY UTENSIL STERILIZERS, *J. E. Nicholas, J. A. Sperry,* and *L. F. Tomey*. Pennsylvania Station Bulletin 296 (1933), pp. 28, figs. 15. Part 1 of the bulletin reports studies of the comparative heating efficiency of different types of sterilizers, and Part 2 reports studies of the bacteriological efficiency of electrically heated dairy utensil sterilizers.

It was found that electrically heated dairy utensil sterilizers are mechanically efficient and economical of operation and meet the requirements of the Pennsylvania Department of Health. The cost of the operation of the electrically heated sterilizer depends on the weight in pounds of the utensils, the quantity of water used, the initial and the final temperatures of the water and the utensils, the heat losses, the time of the season, the size of the heat elements (watts), and the heat capacity of the sterilizer. The heating and sterilizing operations are automatic. There are no open fires, soot, or smoke. The sterilized utensils may remain in the sterilizer until needed. Absolute sterility of milk bottles and dairy utensils is an unattainable goal for practical purposes. Dairy utensils which are bacteriologically clean are as much as may be expected in any dairy.

It was also found that the hot water sterilizer is a good safeguard against the careless washing of milk bottles and dairy utensils on farms having a capacity of 200 bottles a day or less. This sterilizer, however, fails to serve its purpose with any degree of certainty when the temperature of the water falls below 180 deg F. during the process of sterilization. The utensil temperature range for *Escherichia coli* is 160 to 203 deg. A few tests indicate that the utensil temperature for the destruction of *Bacillus subtilis* is 325 deg, using the humidified hot air sterilizer. When operated at the proper temperature, the hot water sterilizer is an excellent apparatus for producing bacteriologically clean dairy utensils.

It is not considered feasible to recommend any definite temperature for the hot air sterilizer. It is considered more advisable to suggest that the destruction of bacteria, except the high-heat-resisting, spore-forming *B. subtilis*, is satisfactorily accomplished after all the moisture from the wet utensils which have been placed in the sterilizer has evaporated. Experience indicated that with this as a guide, utensils may be considered bacteriologically clean and are frequently even sterile.

DAILY RIVER STAGES AT RIVER GAGE STATIONS ON THE PRINCIPAL RIVERS IN THE UNITED STATES, compiled by *M. W. Hayes*. U. S. Dept. Agr., Weather Bur., Daily River Stages, 30 (1933), pp. III+165. This volume, containing the daily river stages for 1932, is the thirtieth of a series.

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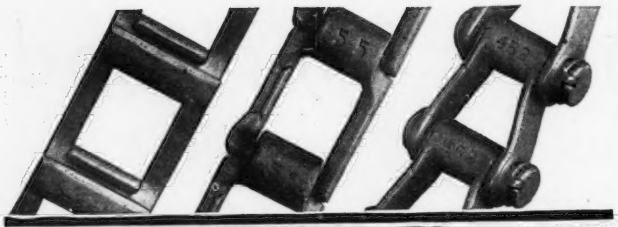

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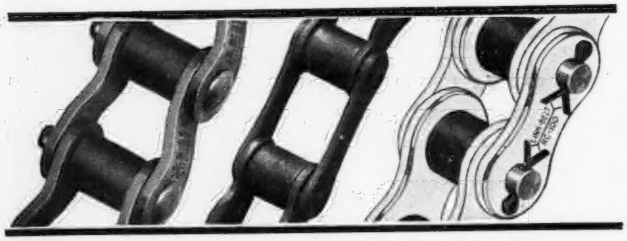

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EMPLOYMENT BULLETIN

An employment service is conducted by the American Society of Agricultural Engineers for the special benefit of its members. Only society members in good standing are privileged to insert notices in the "Men Available" section of this bulletin, and to apply for positions advertised in the "Positions Open" section. Non-members as well as members, seeking men to fill positions, for which members of the Society would be logical candidates, are privileged to insert notices in the "Positions Open" section and to be referred to persons listed in the "Men Available" section. Notices in both the "Men Available" and "Positions Open" sections will be inserted for one month only and will thereafter be discontinued, unless additional insertions are requested.

Men Available

ELECTRICAL ENGINEER, graduate of the University of London, desires employment as rural service engineer or distribution engineer with an electric power company, or as research engineer in rural electrification with an agricultural experiment station, preferably in eastern or western United States. Seven years experience in rural electrification with electric power companies and in research at a state agricultural college. Age 33. MA246.

AGRICULTURAL ENGINEER, graduate of Michigan State College, at present working for master's degree at University of Minnesota (with major in farm power and machinery), desires employment with farm equipment manufacturer either in engineering or sales work. Born and reared on a farm. In connection with college work, he has served as teaching and research assistant, all the work being in farm machinery. Available April 1, 1934. MA247

AGRICULTURAL ENGINEER, graduate of Virginia Polytechnic Institute and licensed surveyor, with varied experience in surveying and construction work, and three years' carpentry experience, desires employment as surveyor or with construction company. Single. Age 27. Will go anywhere. MA248

AGRICULTURAL ENGINEER with both bachelor and master of science degrees (majoring in agricultural engineering) from midwest universities, two summers' experience as irrigation investigation engineer in midwest state, experience in soil erosion work, and five years' experience with agricultural engineering department of large university where the duties consisted of research work in reclamation, farm development, land use study, and a regular teaching schedule mainly in reclamation, desires employment where qualifications meet the need, preferably with farm equipment company, in federal work, or in agricultural engineering with some state agricultural college. Married. Age 27. MA249

AGRICULTURAL ENGINEER, graduating this June as a member of the first agricultural engineering class from University of Illinois, with twelve years' experience as draftsman, tool and jig designer, designer of automatic machinery, and foreman of mechanical research and development department. Prefers to locate in the Southwest. Available July 1. Age 40, married. MA-251

AGRICULTURAL ENGINEER, with bachelor of science degree from Montana State College, and master's degree from Iowa State College with major in vocational education and minor in agricultural engineering, who for the past four years has been working on an advanced degree in agricultural engineering on a part time basis; who is a qualified Smith-Hughes vocational agriculture instructor; who has had eleven years' teaching experience, including five years as instructor in farm mechanics in agricultural engineering department of Iowa State College, and who has served as supervisor of practice teaching in farm mechanics for the vocational education department of I.S.C. for the past three years, desires position as instructor in agricultural engineering in some state agricultural college. Married. Age 36. MA-252

RURAL ELECTRIC ENGINEER with bachelor's degree from an eastern state college (1928) now employed by one of the largest public utilities in the East, desires a change of location where remuneration is dependent upon the individual's merits. He is experienced in all farm operations, thoroughly understands rural problems, has had six years' experience in rural electrification, and has also taken the rural electrification course offered by General Electric Company. He would be interested preferably as rural electrification engineer with a public utility, in experiment station research work, with an equipment manufacturing concern, or as a graduate assistant. Age 29. Single. Will go anywhere. MA-253

Position Open

ENGINEER wanted. Must have experience in design, development, and experimental work relating to farm machinery, preferably tillage. Must be 35 to 40 years of age, have experience in handling men, and ability to cooperate with production departments. Graduate engineer desired, but not necessary. In replying, give age, education, experience in detail, salaries received and expected. PO-101